Lecture
Module 8: Nutrient Cycling

Stan Gregory
Department of Fisheries and Wildlife
Oregon State University

Learning Objectives

Upon completion of this module, the participant will be able to:

1. Describe the various biotic and abiotic pathways of the major nutrients (C, N, P, K) through terrestrial and aquatic ecosystems.

2. Describe oligotrophic and eutrophic aquatic ecosystems and the processes that lead to these conditions.

3. Understand the spatial scale of effects of nutrient enrichment and depletion on biotic communities and their social and economic consequences.

Lecture Outline

- Major biologically important nutrients
  - Carbon
    - Sources
    - Dissolved vs. particular organic carbon (DOC vs POC)
    - C/N ratios
    - Refractory vs. labile compounds
  - Nitrogen
    - Nitrogen cycle
  - Phosphorus
    - Sources
    - Redfield ratio (N/P)
- Nutrient cycling
  - Nutrient spiraling
  - Flux and uptake
  - Retention
- Hypoxia in the Gulf of Mexico
  - Causes and consequences
  - Economic impact
  - Sources of nitrogen inputs—Upper Midwest
  - Changes in Mississippi
- Management implications and solutions

Exercises

A) Classroom Exercises:

1. A point-source discharge increases the concentration of nitrate to 1 mg/L of NO3-N. You go downstream 100 m and find that the concentration is 0.70 mg/L. What is the average travel distance of a nitrate molecule in this stream?

2. For each of the types of nitrogen transformation described below, fill in the missing information. "Transformation" refers to the name of the process. "Source" refers to the initial form of nitrogen and "product" refers to the final form of nitrogen for that type of transformation. "Organism" refers to the type of organism that is capable of each type of transformation (be as specific as possible). For the type of organism indicated, indicate whether the process occurs in aerobic habitats, anaerobic habitats, or both.

Transformation	Source	Product	Organism	Aerobic or Anaerobic
	NO_3^-	N_2	Bacteria	
	N_2			Aerobic
	Dissolved organic N	NH_4^+	Bacteria	Both
			Nitrobacter	

B) Field Exercise: Retention in Streams

The interface between terrestrial and aquatic ecosystems—riparian areas—strongly influences the production and input of food resources. Terrestrial ecosystems deliver large amounts of allochthonous organic material to streams and rivers. While the forms and amounts of allochthonous inputs are critical components of the food base, this material must be retained before it can be consumed or used as physical habitat. The process of retention is the removal of either dissolved or particulate material from transport by physical trapping of particulate matter, deposition of particulate matter, biological uptake of both dissolved and particulate material, or physical adsorption of dissolved material. Complex, rough stream channels retain material in transport more efficiently than simple, uniform channels.

After a quantity of material enters a stream, the proportion suspended in the water column will decrease exponentially as it is transported downstream (Figure 1).

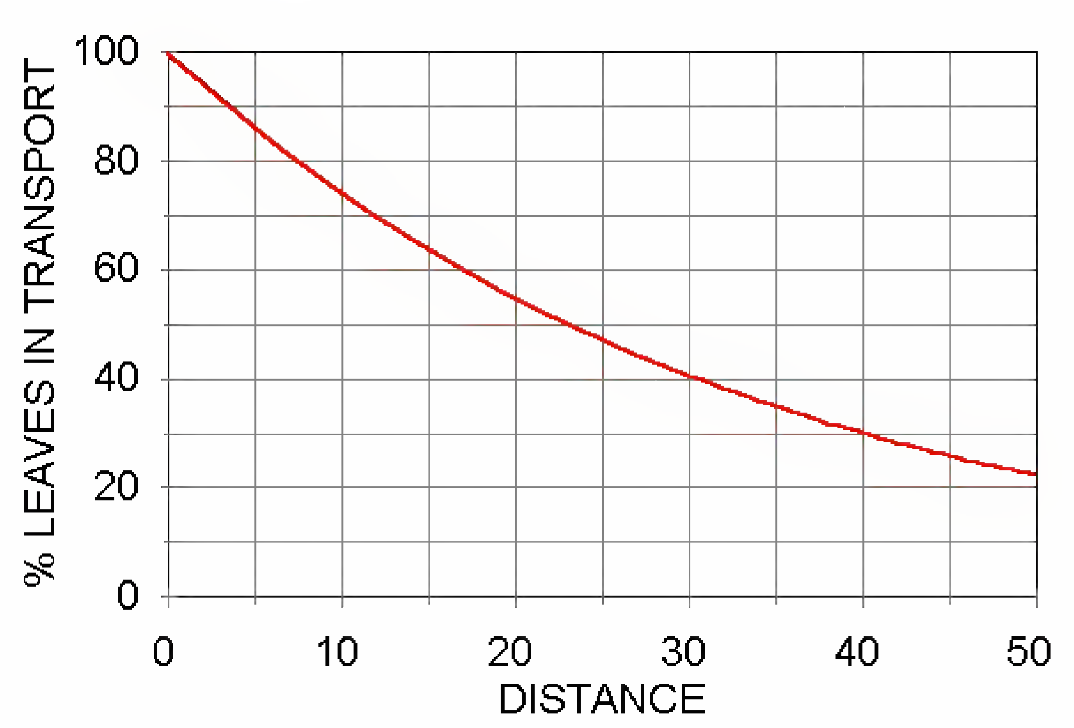

Figure 1. Percent of leaves in transport as a function of distance downstream from the point of entry.

The retention of material in transport in a stream is based on a simple negative exponential model. This same relationship also is used to represent light extinction, decomposition of detritus, biotic uptake of dissolved nutrients, and radioactive decay (Equation 1).

(Equation 1) $$L_d = L_0 \, e^{-k\,d}$$

or

$$\ln L_d = \ln L_0 - kd$$

where L_d = number of leaves in transport at distance d
L_0 = original number of leaves in transport
k = instantaneous retention coefficient
d = distance

Based on this negative exponential relationship, a constant proportion of the leaves will be removed from transport or a given increment of distance downstream. The retention coefficient, k, is the instantaneous rate of retention. The average travel distance for a particle can be calculated by the inverse of the retention coefficient, 1/k.

Procedure

Leaf retention

1. Each group will be assigned to a specific 45-m section within the reach and will place a seine at the bottom of the 45-m section.
2. Leaves will be counted before the lab and soaked in water for 24 hr to make certain that all leaves are neutrally buoyant. Ginkgo leaves (*Ginkgo biloba*) will be used as tracer leaves because they are not commonly found along most streams, they are bright yellow and can be seen easily, and they are tough and resistant to fragmentation when dried and stored.
3. The leaves will be released into the stream carefully distributing them across the channel and avoiding clumping.

Dye

1. After 1 hr, all leaves that reached the bottom net will be collected and counted.
2. Immediately after the initial leaf release, each group will dissolve 5 g of fluorescein dye in 1 L of stream water.
3. A person at the top end of the section will coordinate with a person at the lower end. At a predetermined signal the dye will be poured into the center of the channel at the top of the section.
4. The person at the lower end will record the time that it took the dye to appear visually at the lower end of the section as a measure of maximum velocity.
5. They will also record the time at which the dye is flushed from the section and can no longer be seen. The time that is halfway between the maximum velocity and final clearance will be used as a measure of median velocity.

Measures to be Included in Project Reports

Calculate the retention coefficients and travel distances for the four 45-m sections and determine averages for the larger study reach.

- Retention coefficient for each section (45 m)
- Average leaf travel distance for each section (45 m)
- Average retention coefficients for the reach
- Average leaf travel distances for the reach
- Maximum velocity for each section
- Median velocity for each section
- Average maximum velocity for the reach
- Average median velocity for the reach

Study Questions

1. Nutrients such as carbon, nitrogen, and phosphorus undergo intricate cycles in terrestrial systems, all of which are influenced by soils, plants, water, bacteria and animals. What attributes of terrestrial systems are important for efficient cycling of nutrients?

2. Define the concept of nutrient spiraling. Provide a general equation to explain your definition.

3. Explain how the conversion of braided river reaches to a single channel would affect the spiraling length of dissolved nutrients. Explain how you can determine this through your knowledge of flux and uptake.

4. How could low dissolved oxygen concentrations in the Gulf of Mexico be related to use of fertilizers in the mid-West? What is the term used for the extremely low dissolved oxygen concentrations? Is the Gulf of Mexico the only location where this phenomenon has been observed?

5. Define Redfield ratio and give a practical application of this "rule of thumb" that would contribute to solving the problems of hypoxia in coastal areas of the contiguous US

6. What practices can be undertaken to minimize formation of hypoxia in coastal waters?

References and Selected Reading

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Slides used in lecture

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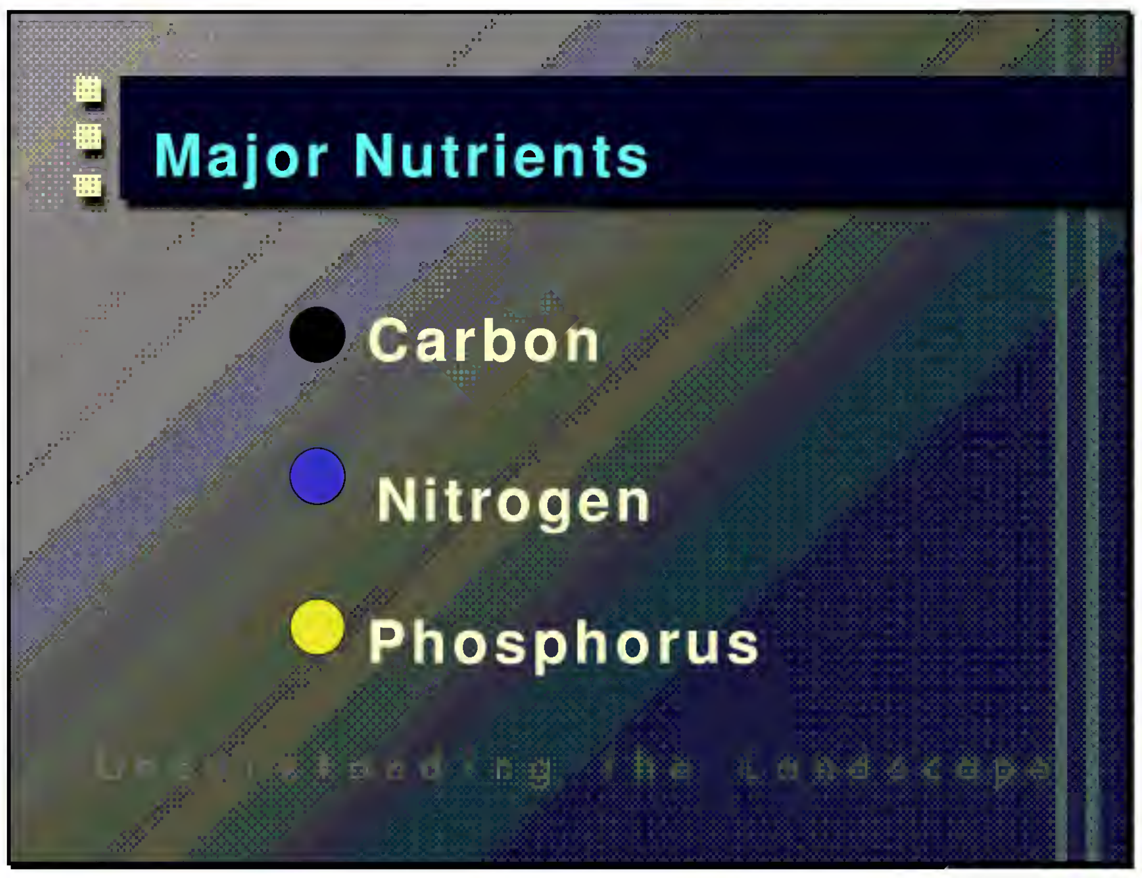

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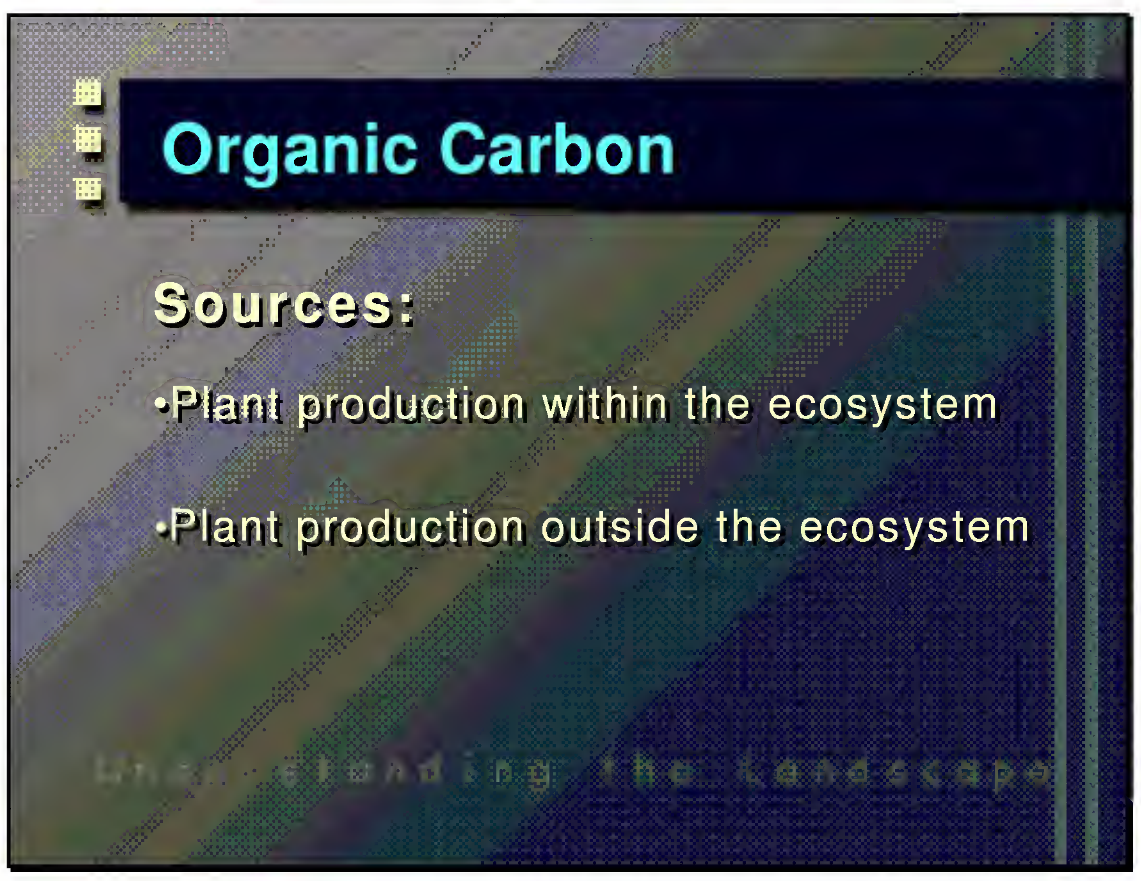

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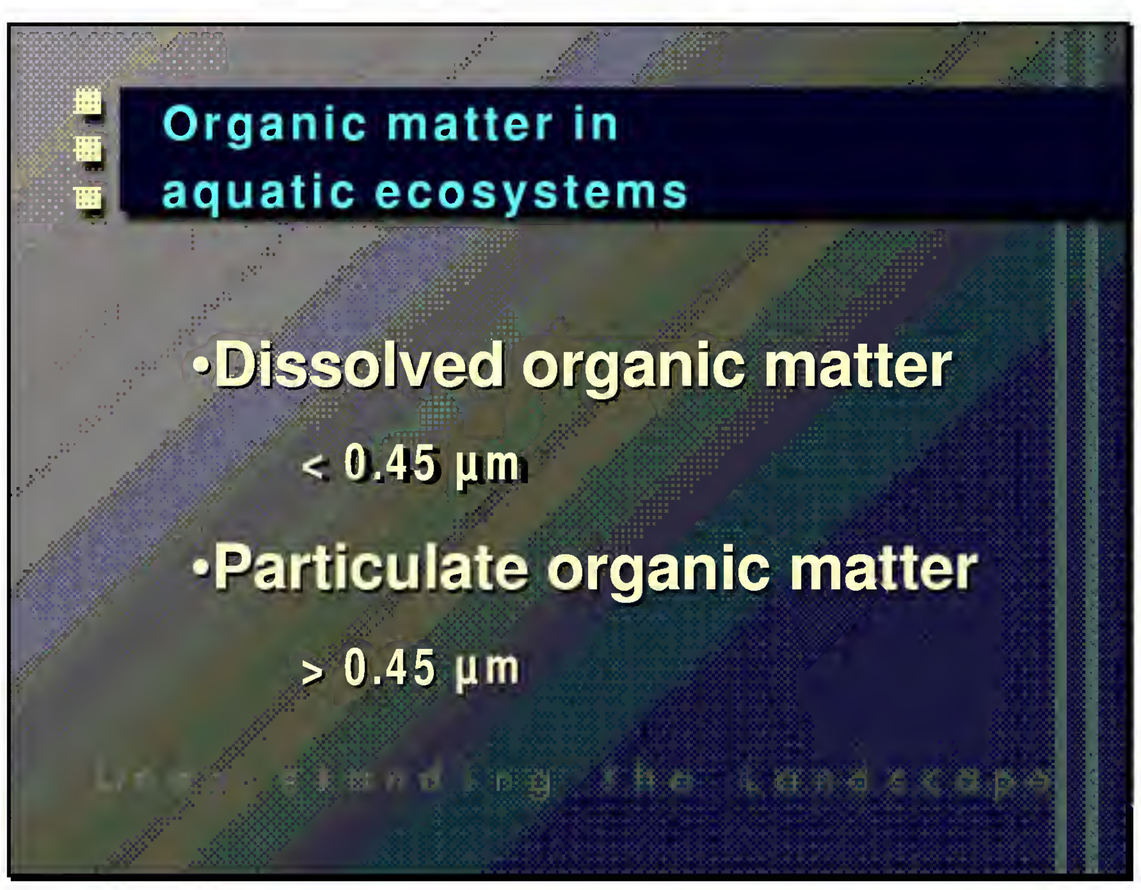

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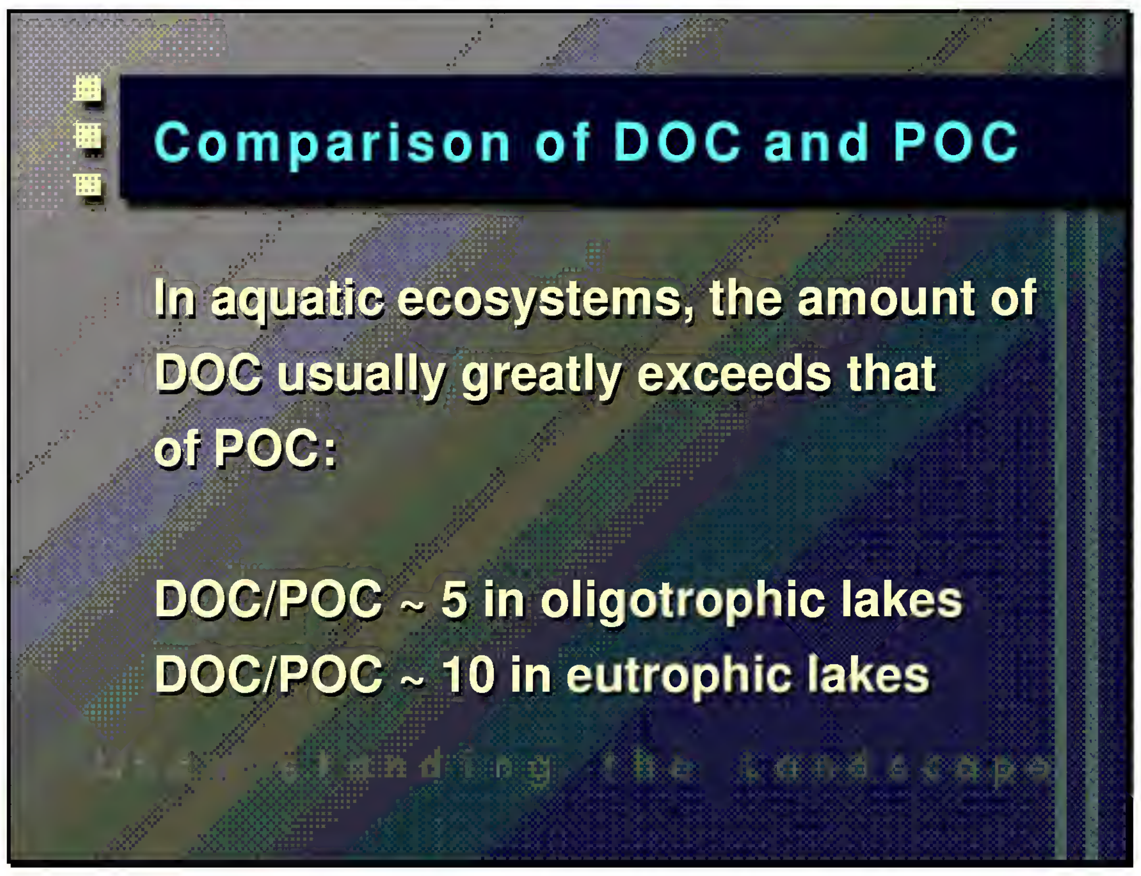

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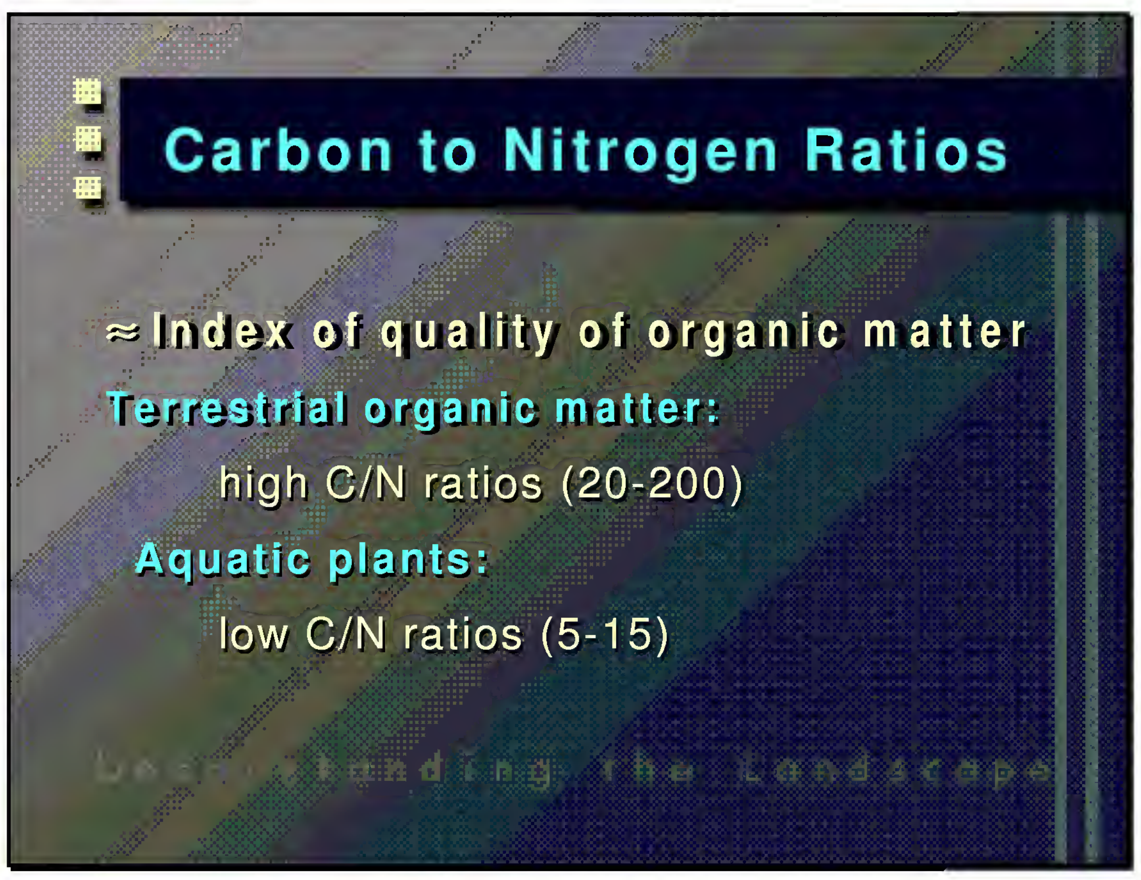

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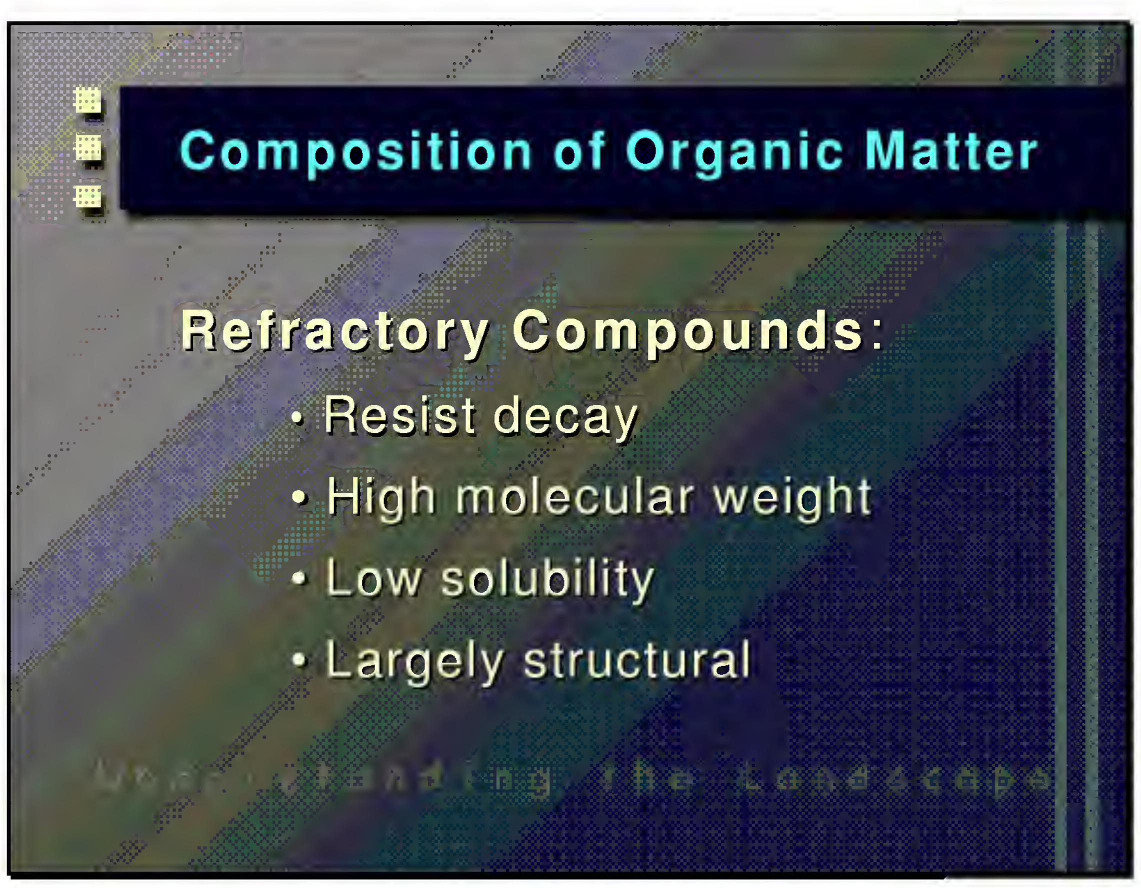

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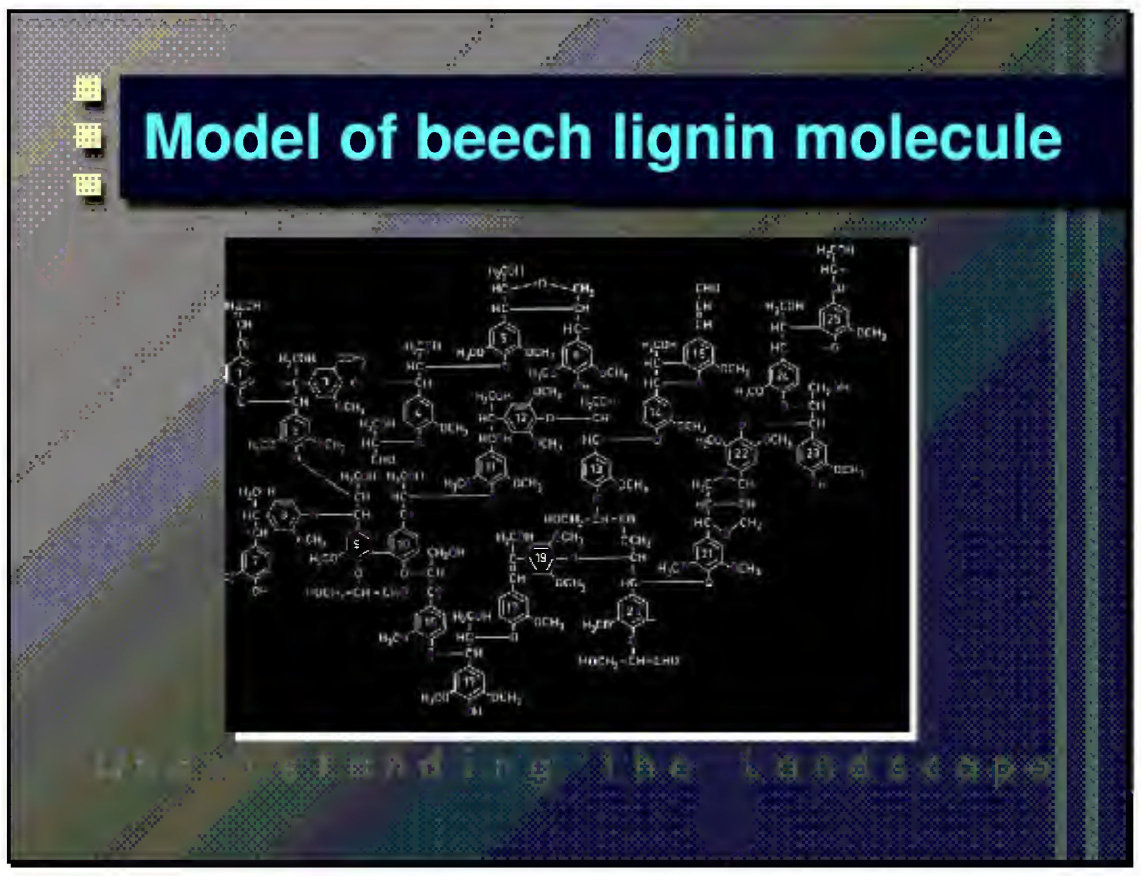

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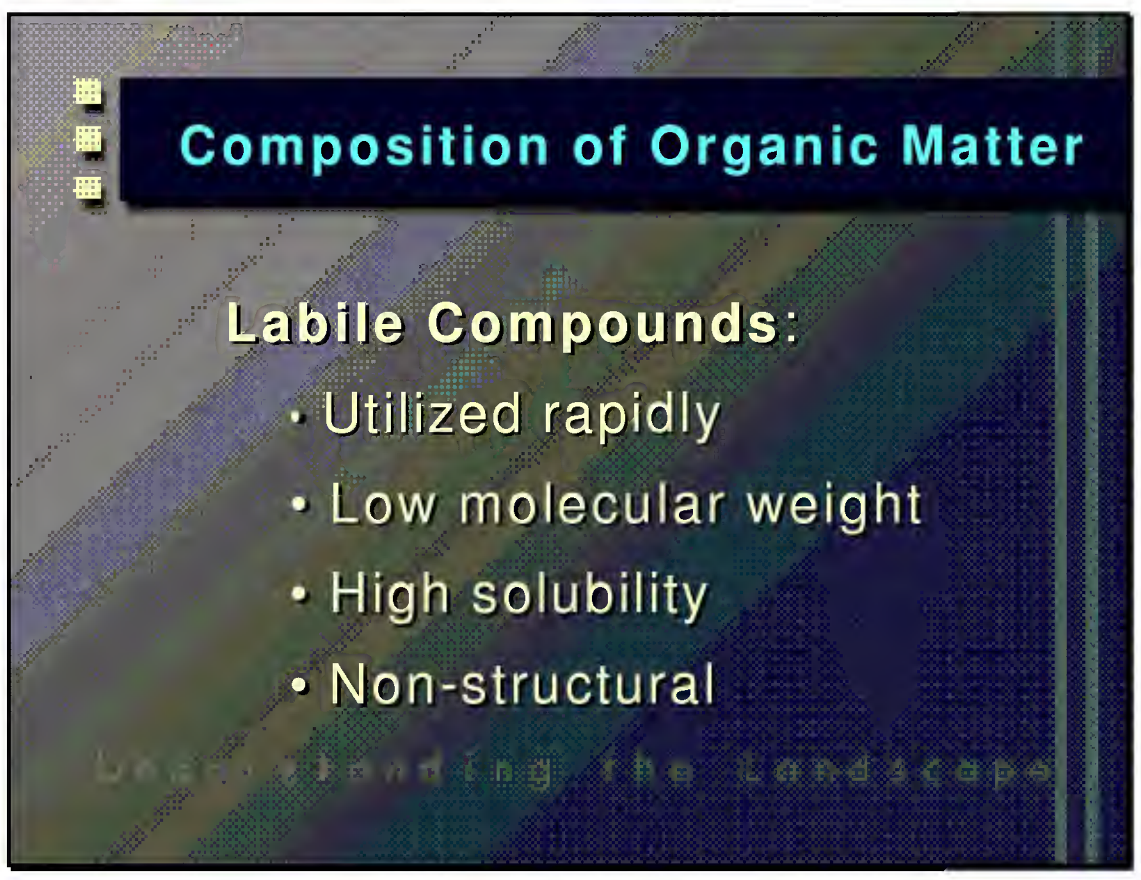

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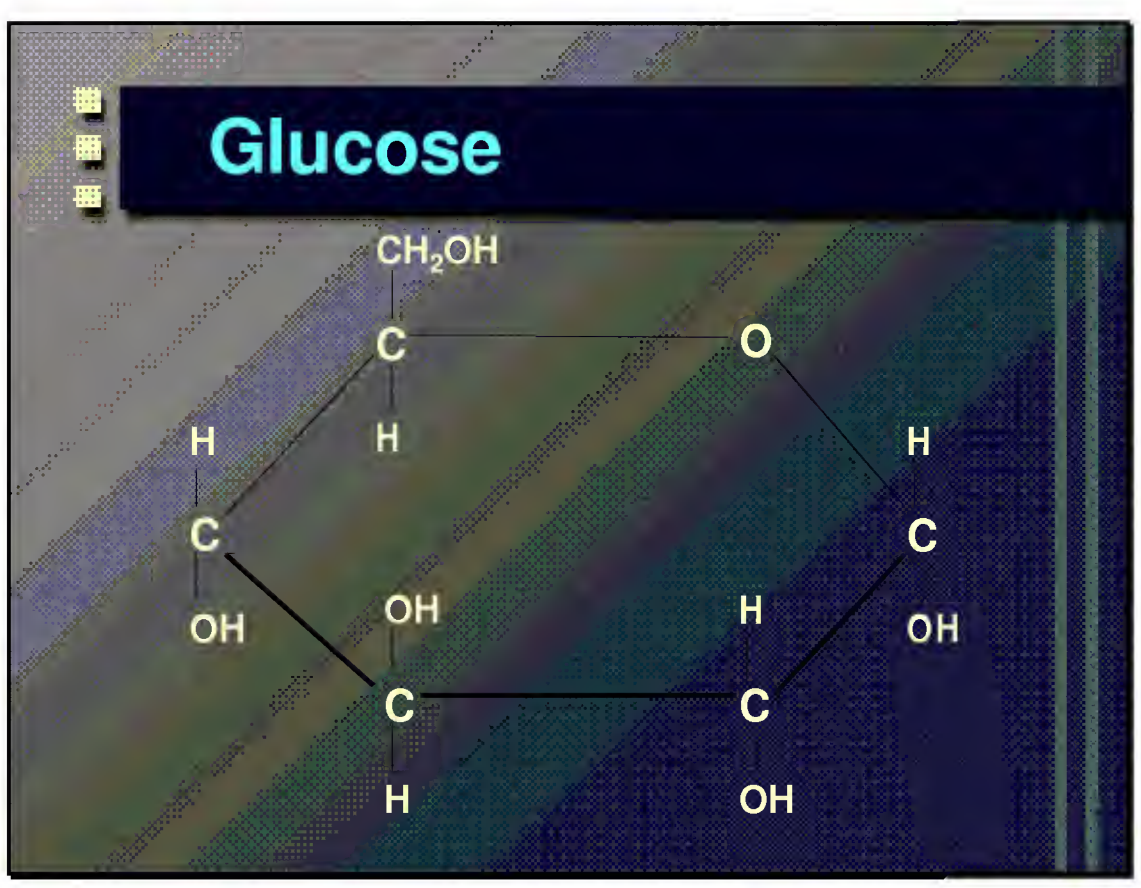

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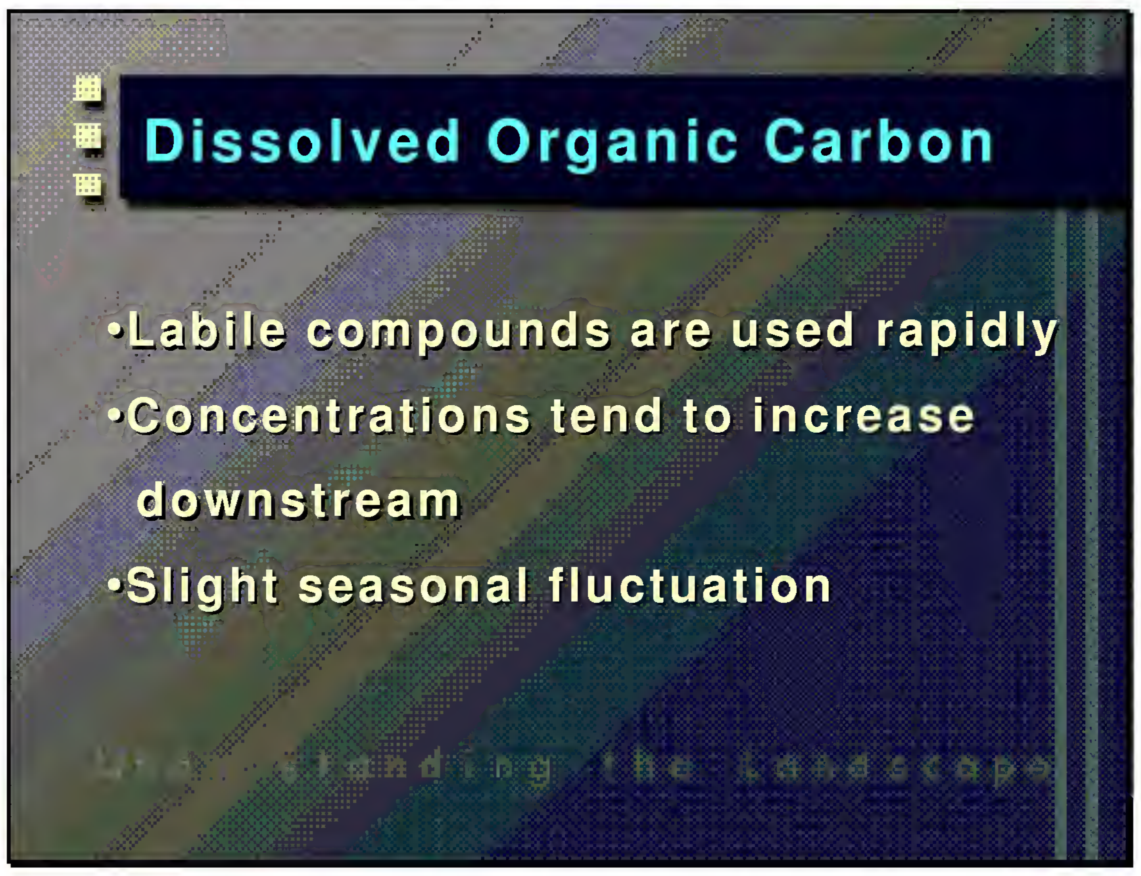

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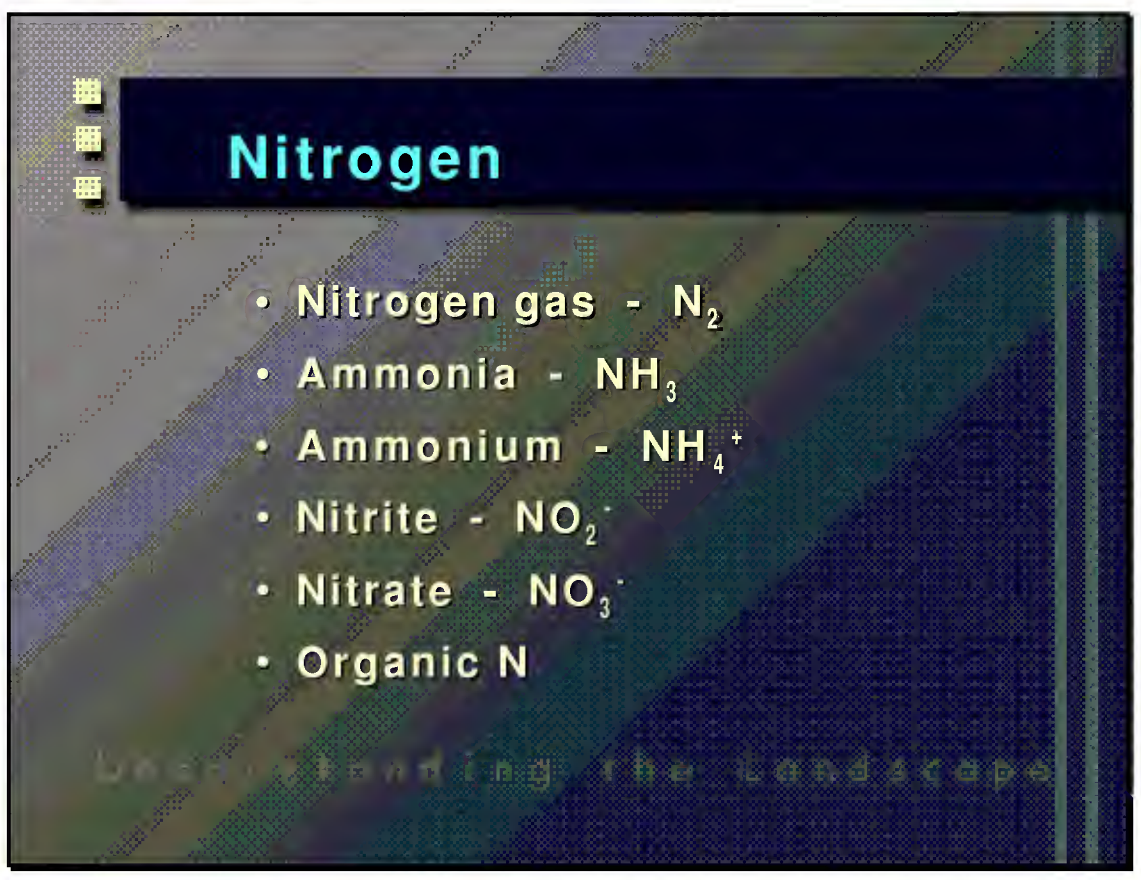

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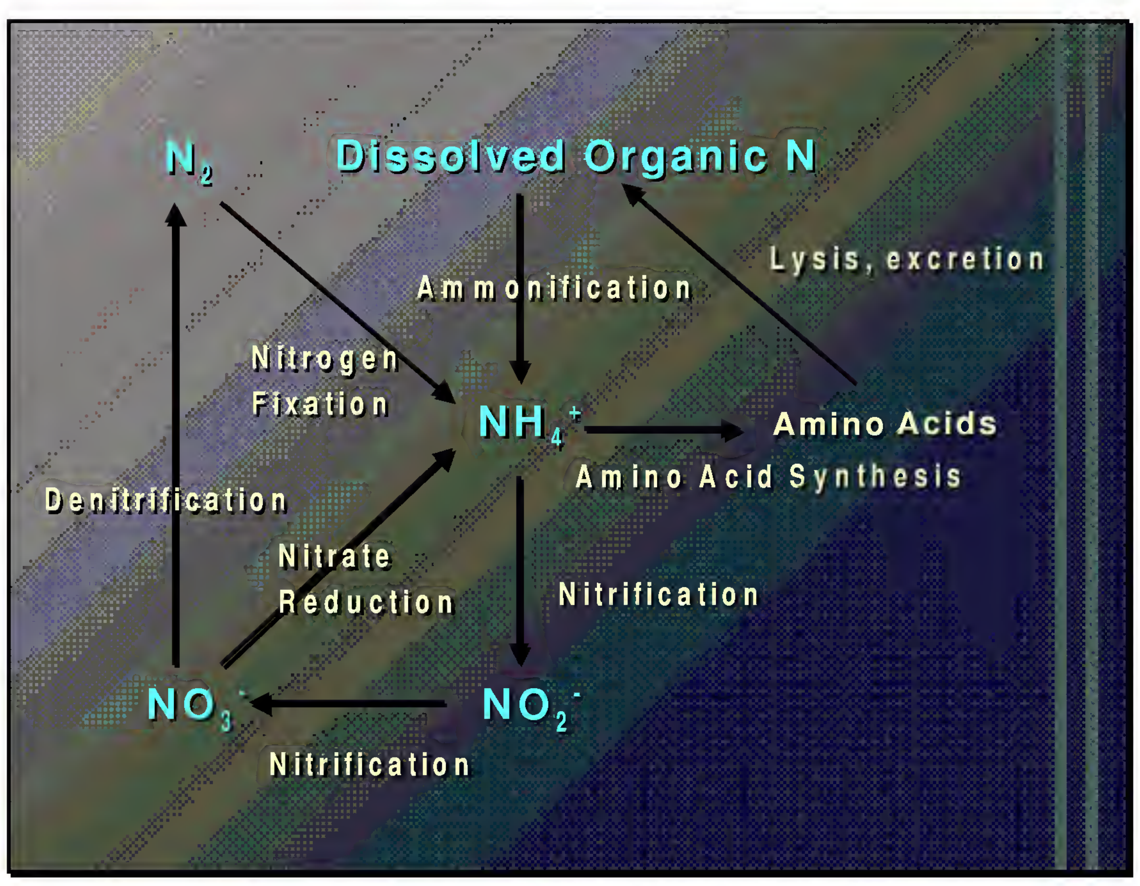

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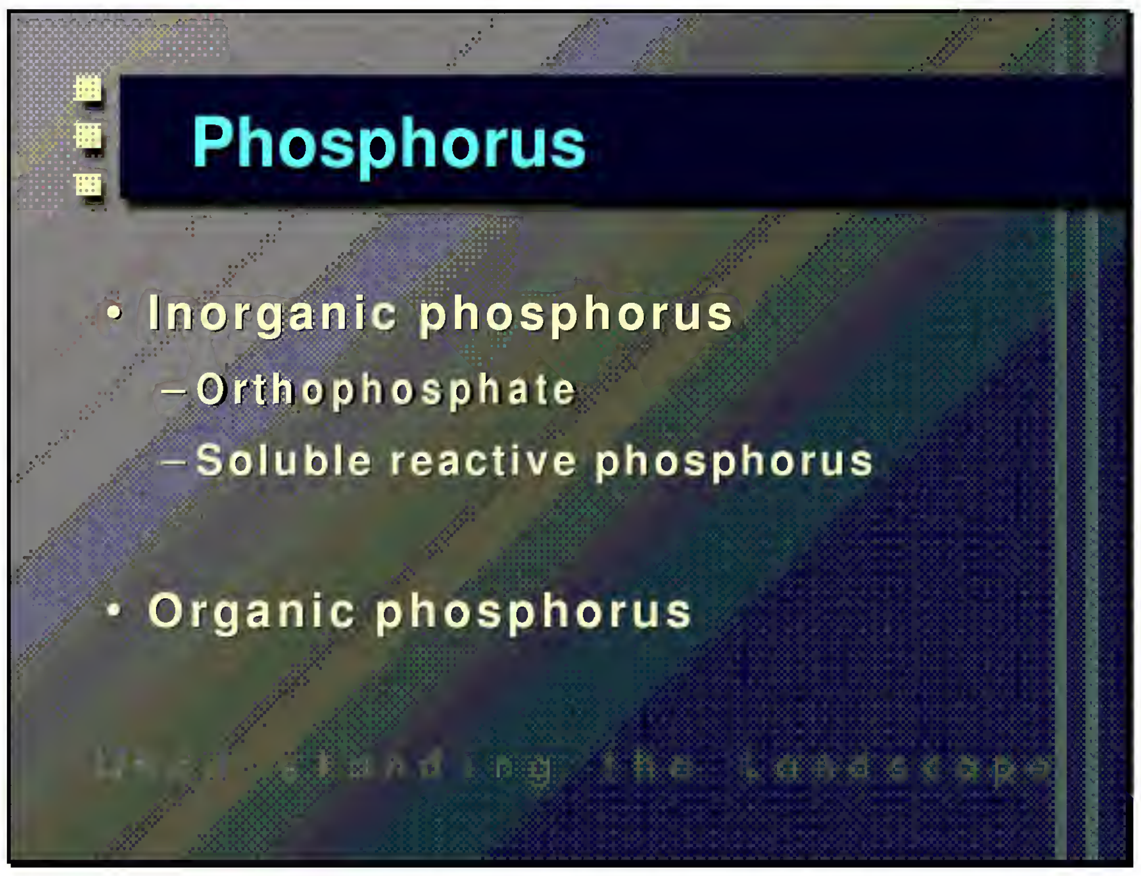

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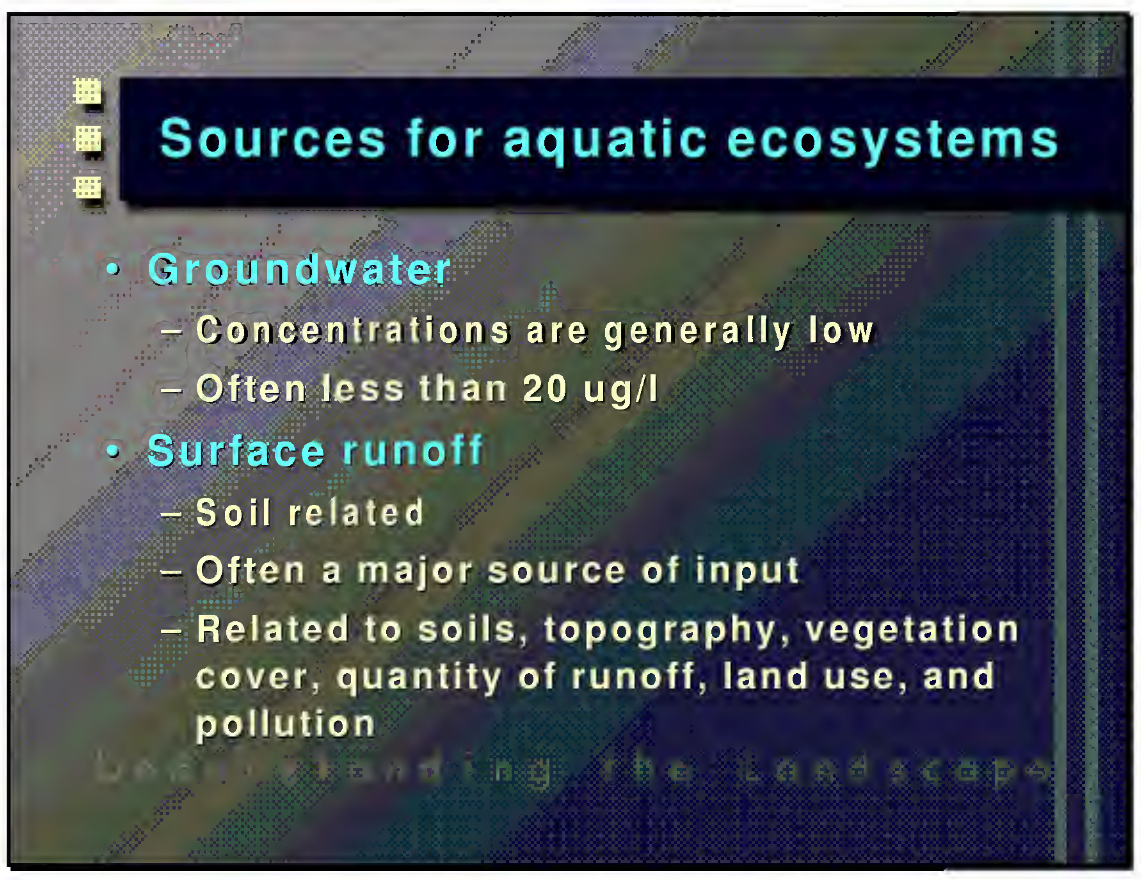

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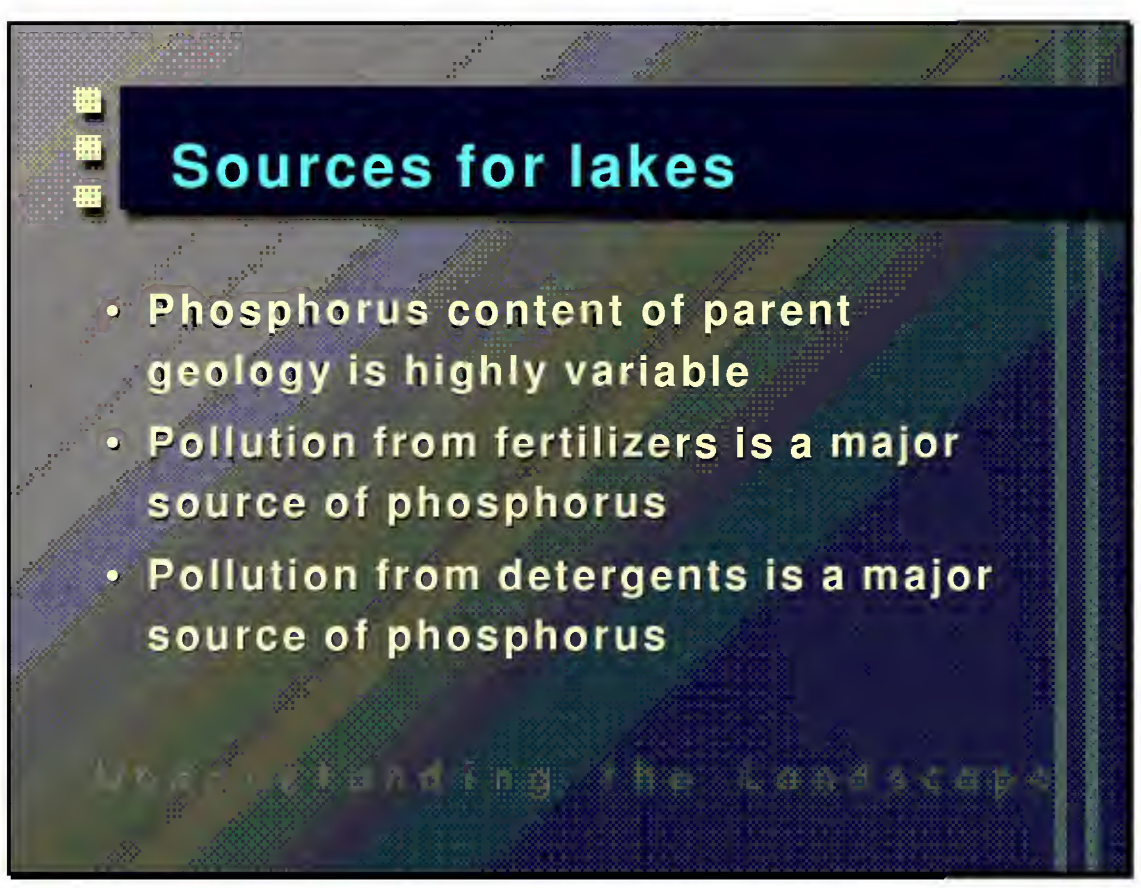

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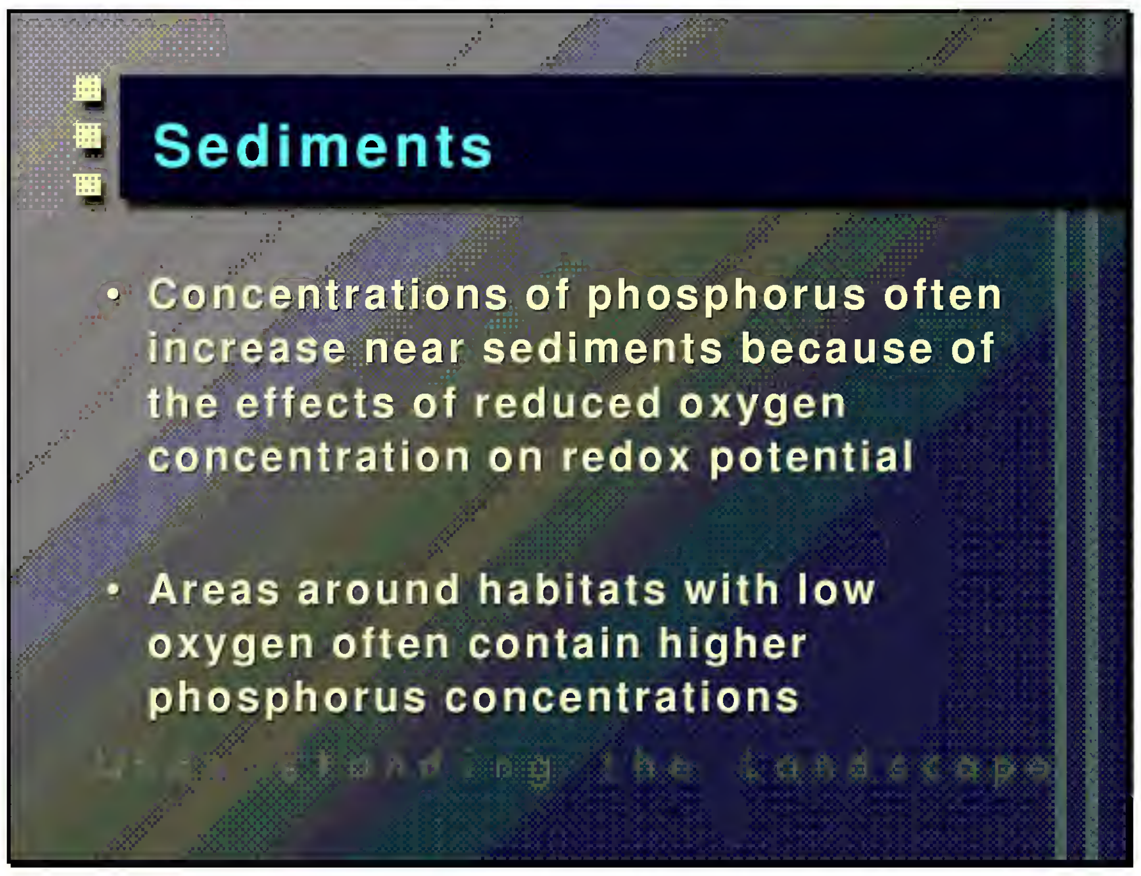

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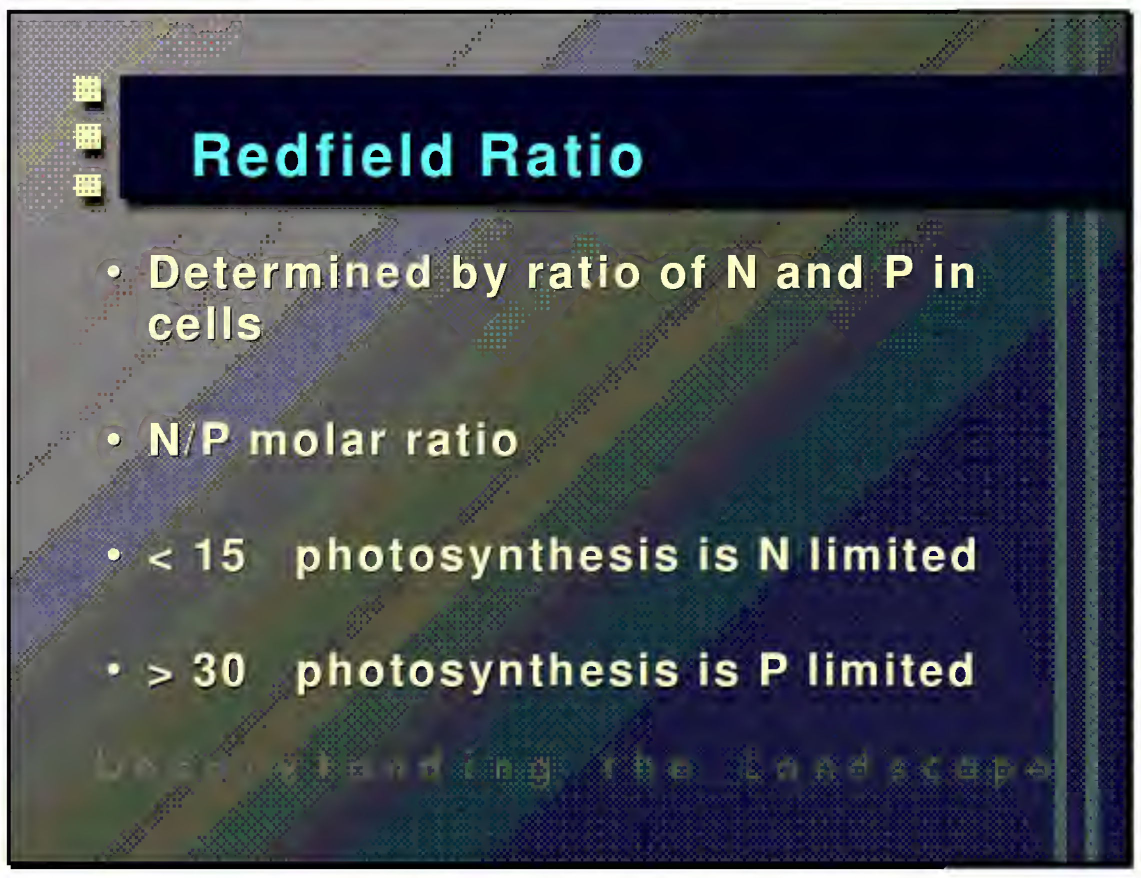

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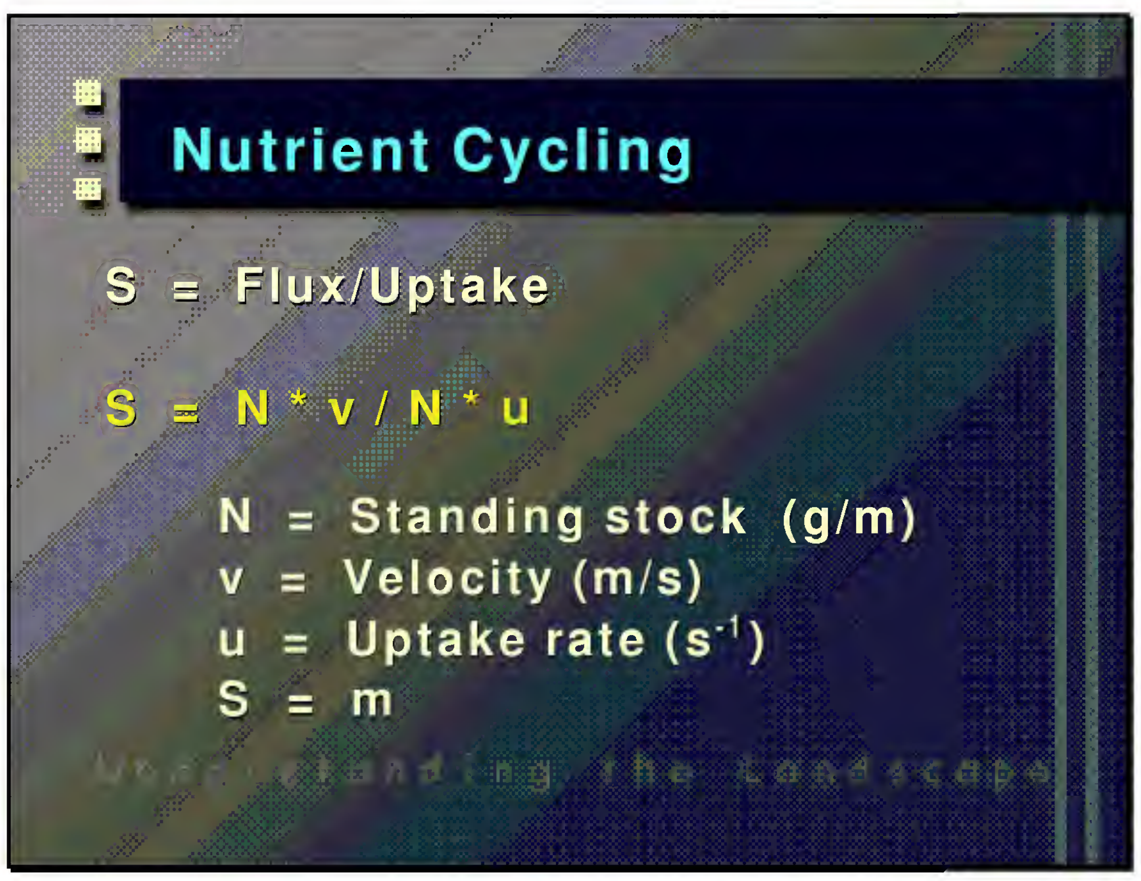

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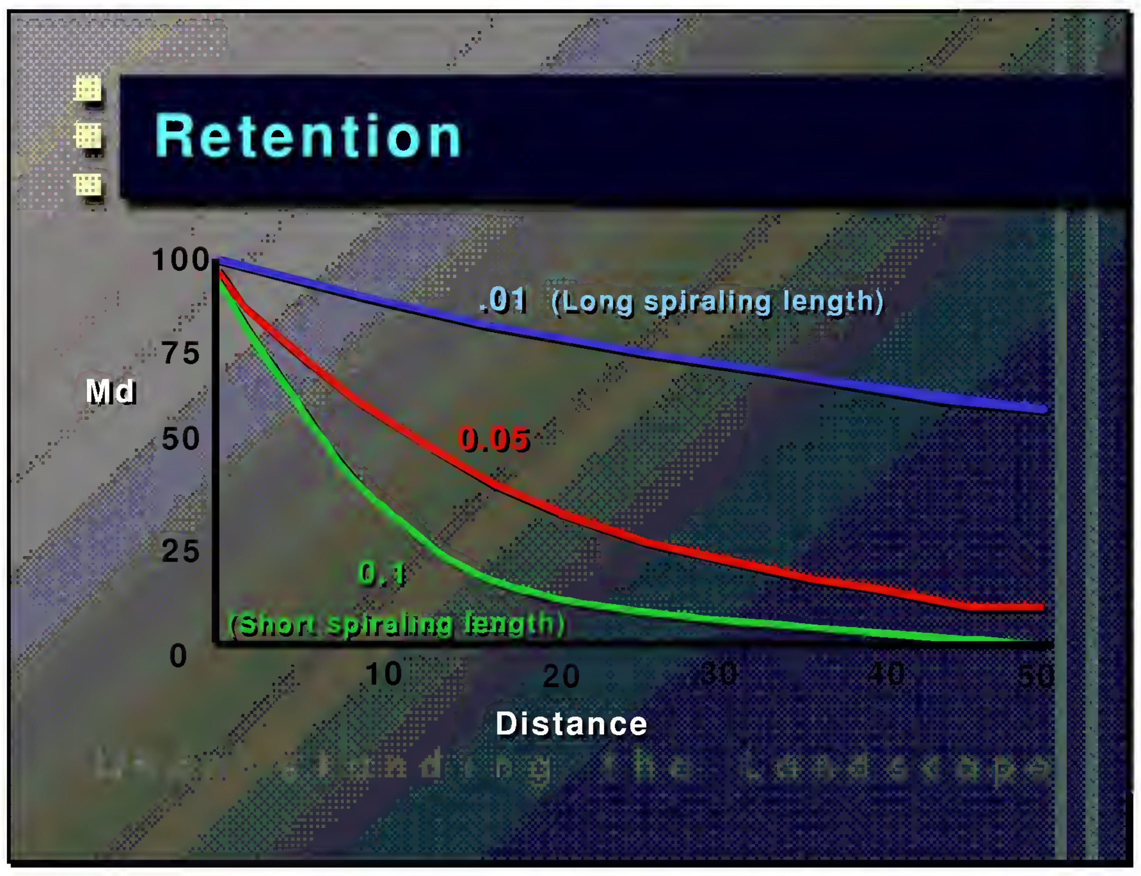

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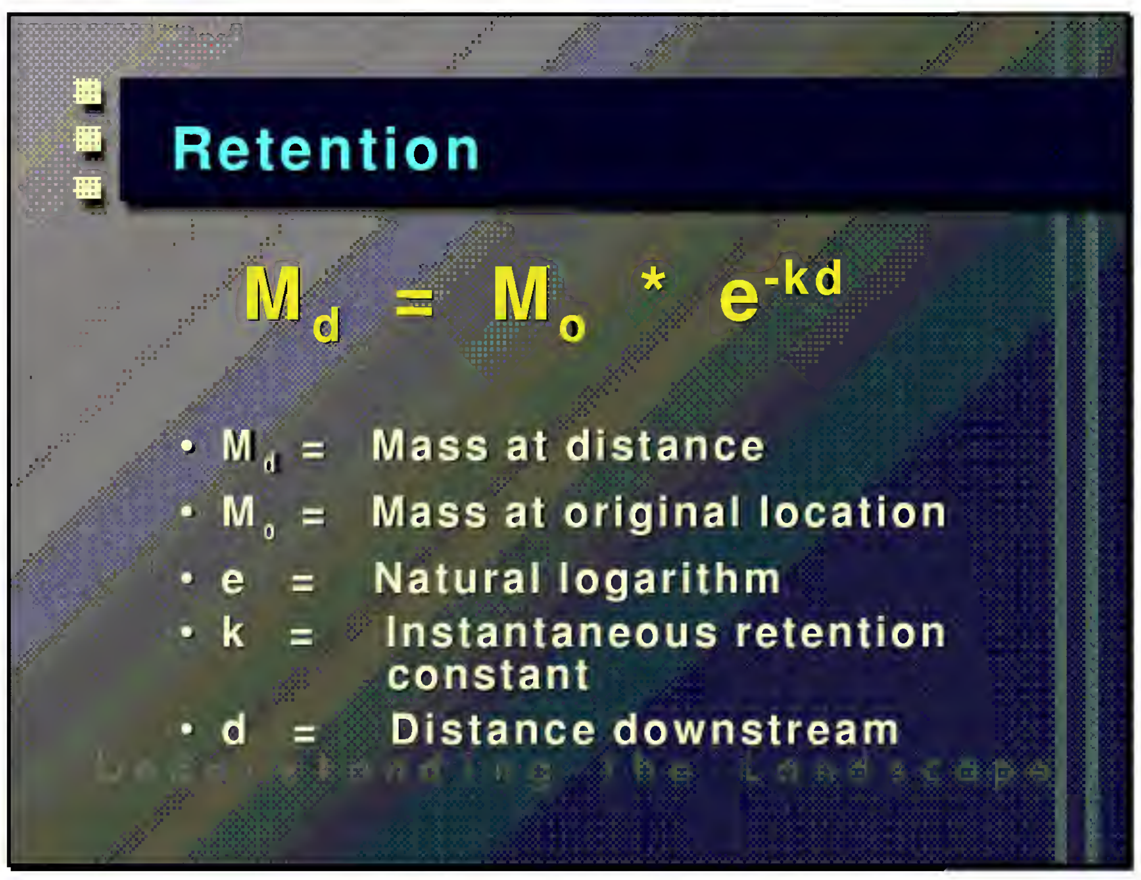

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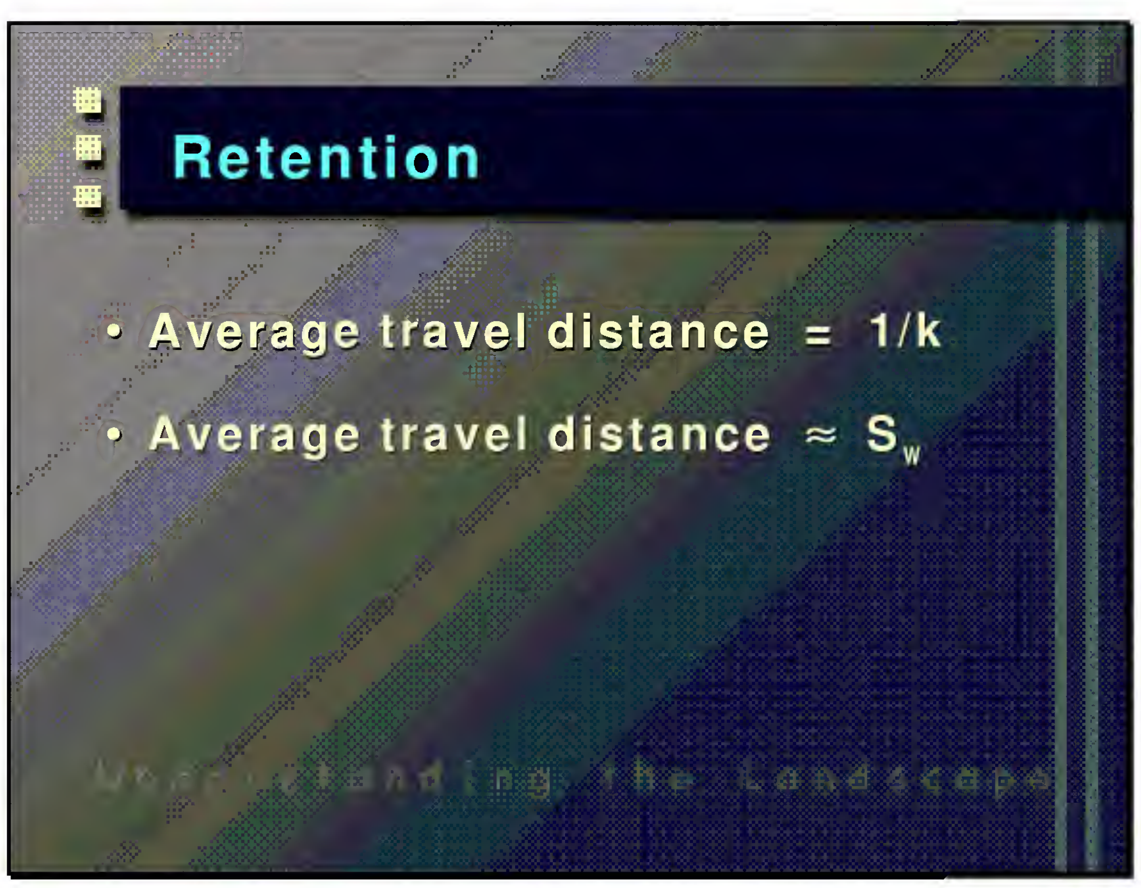

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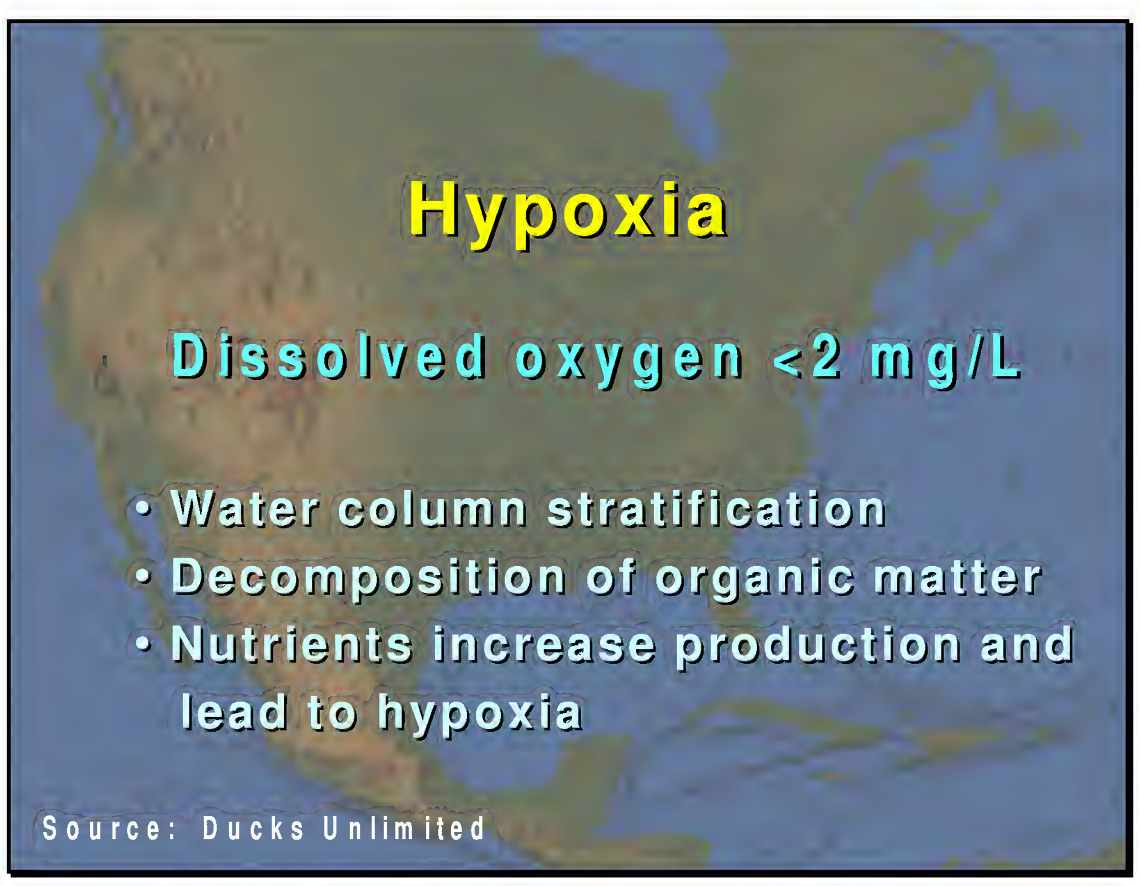

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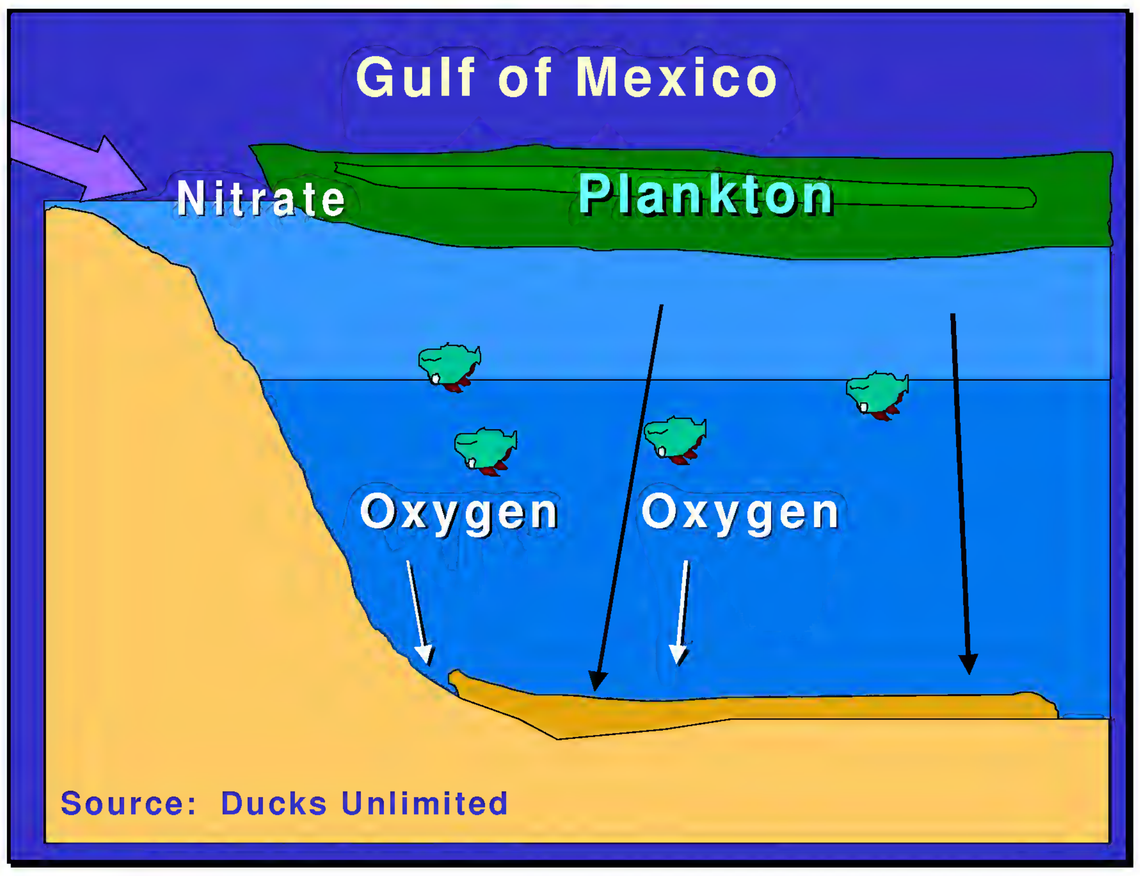

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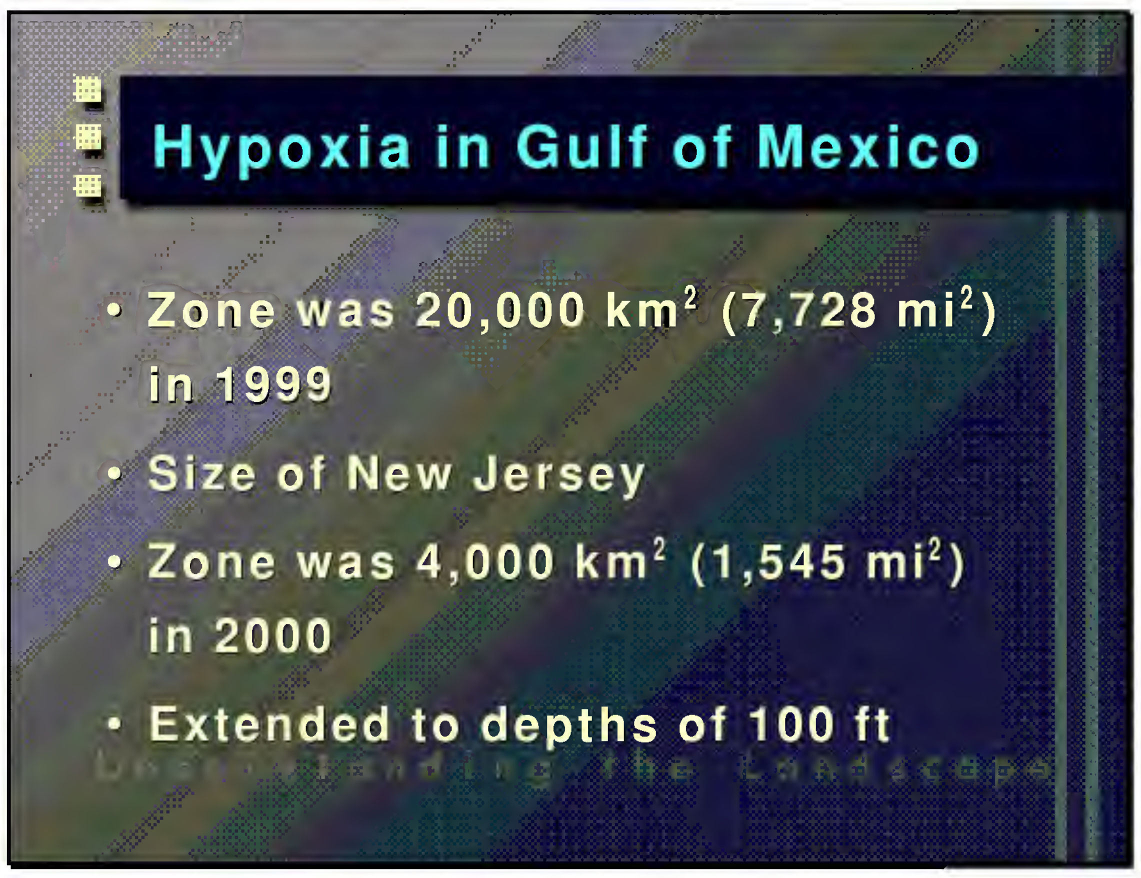

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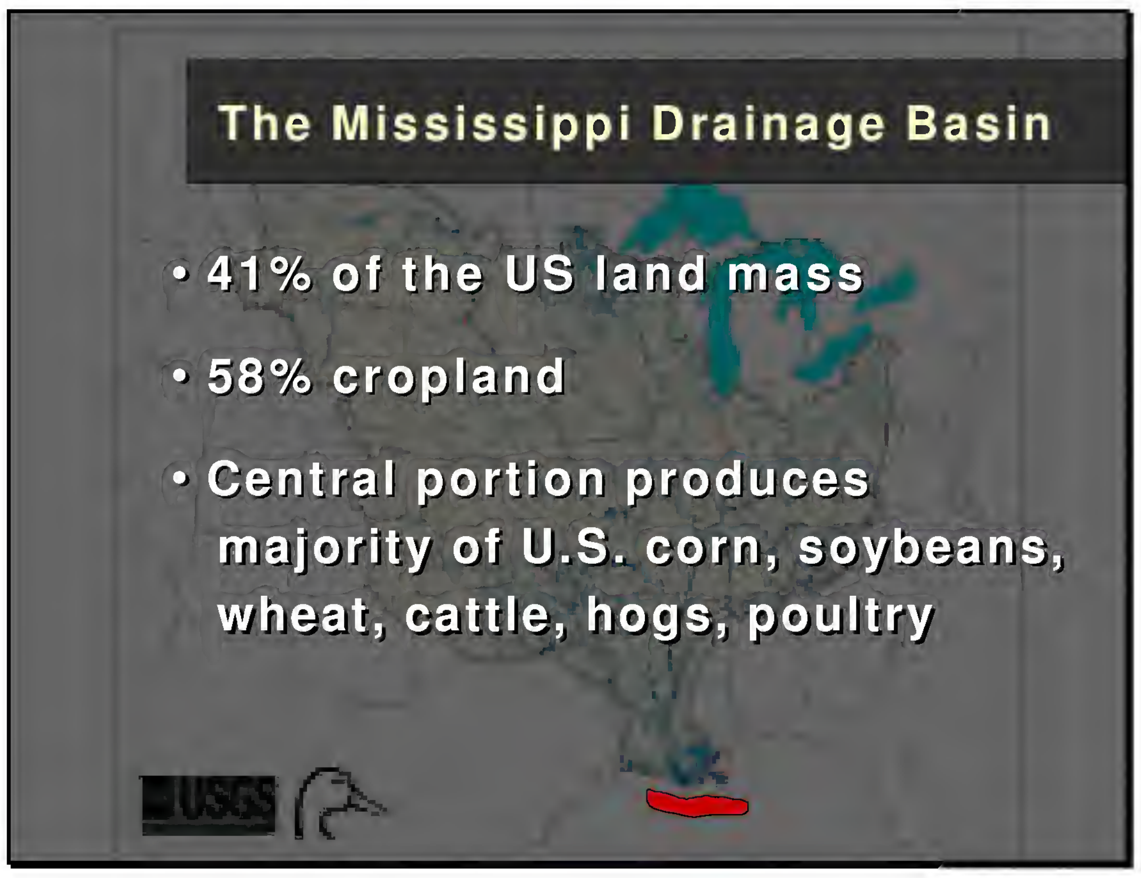

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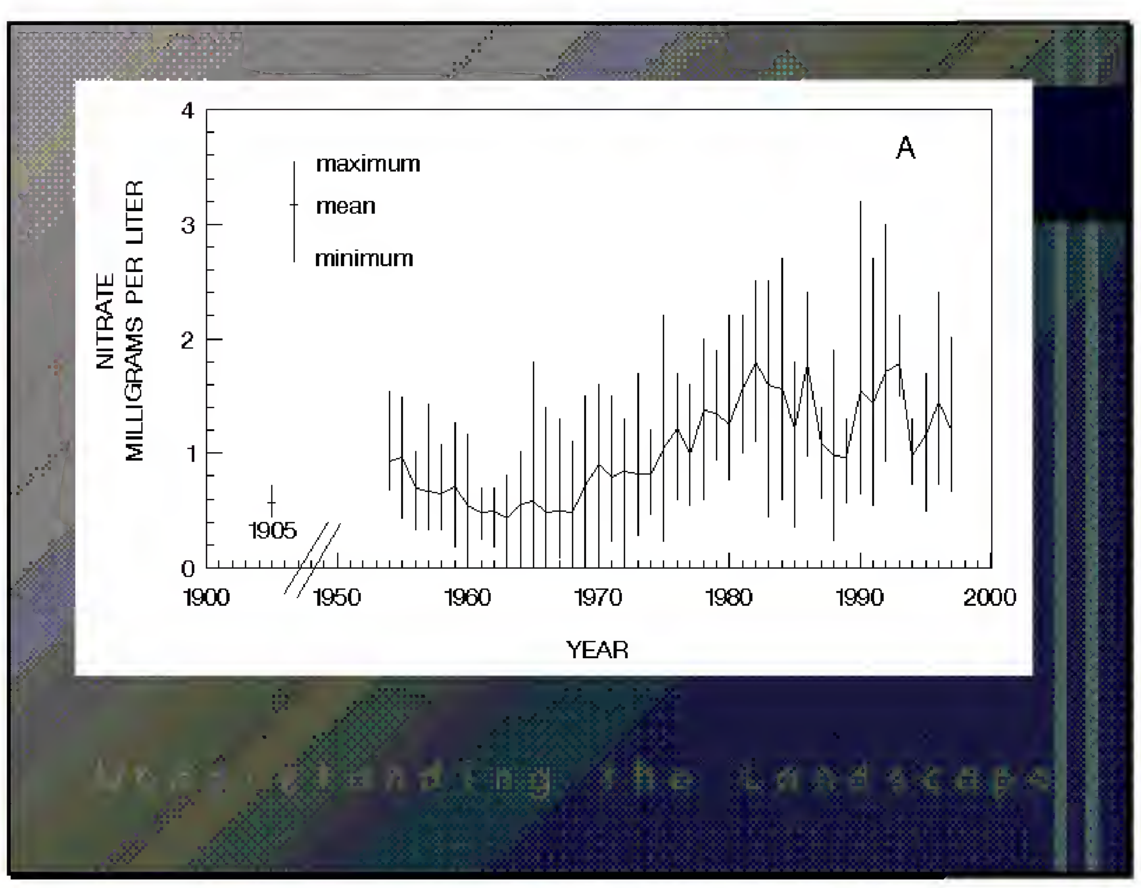

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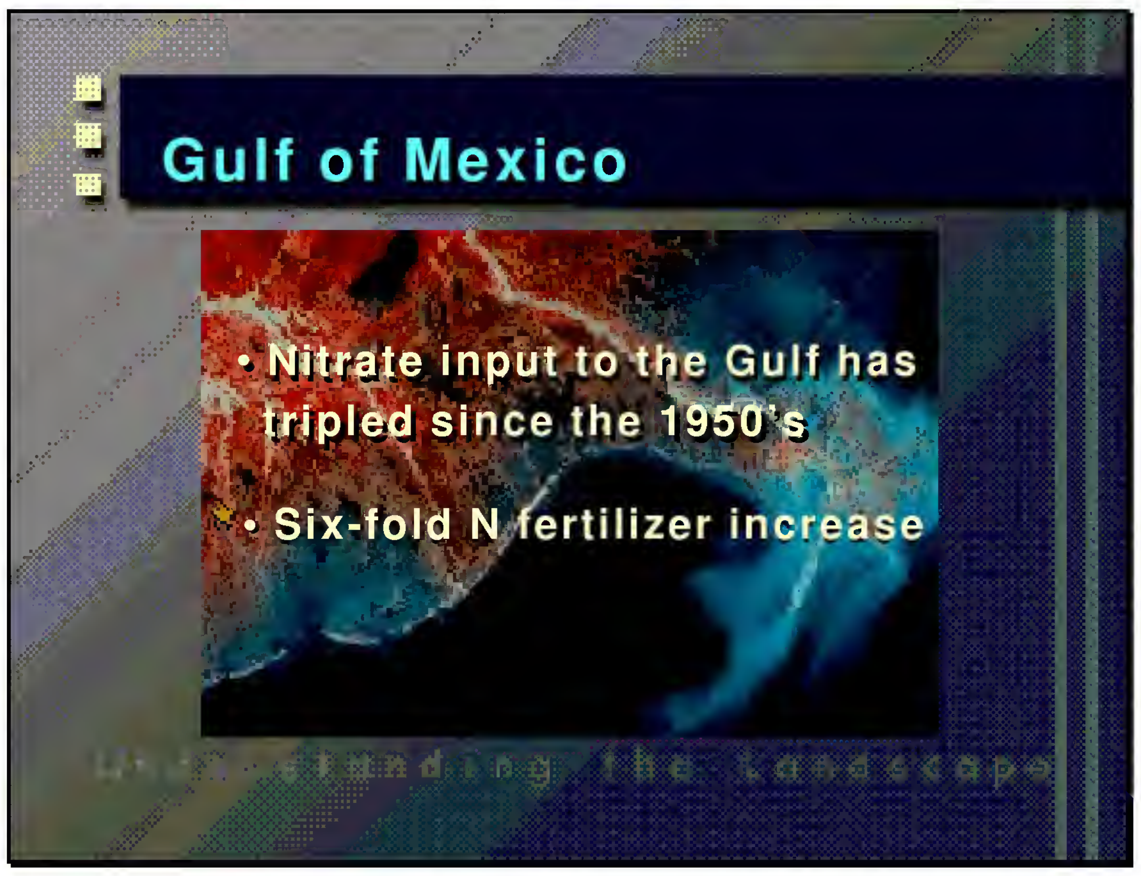

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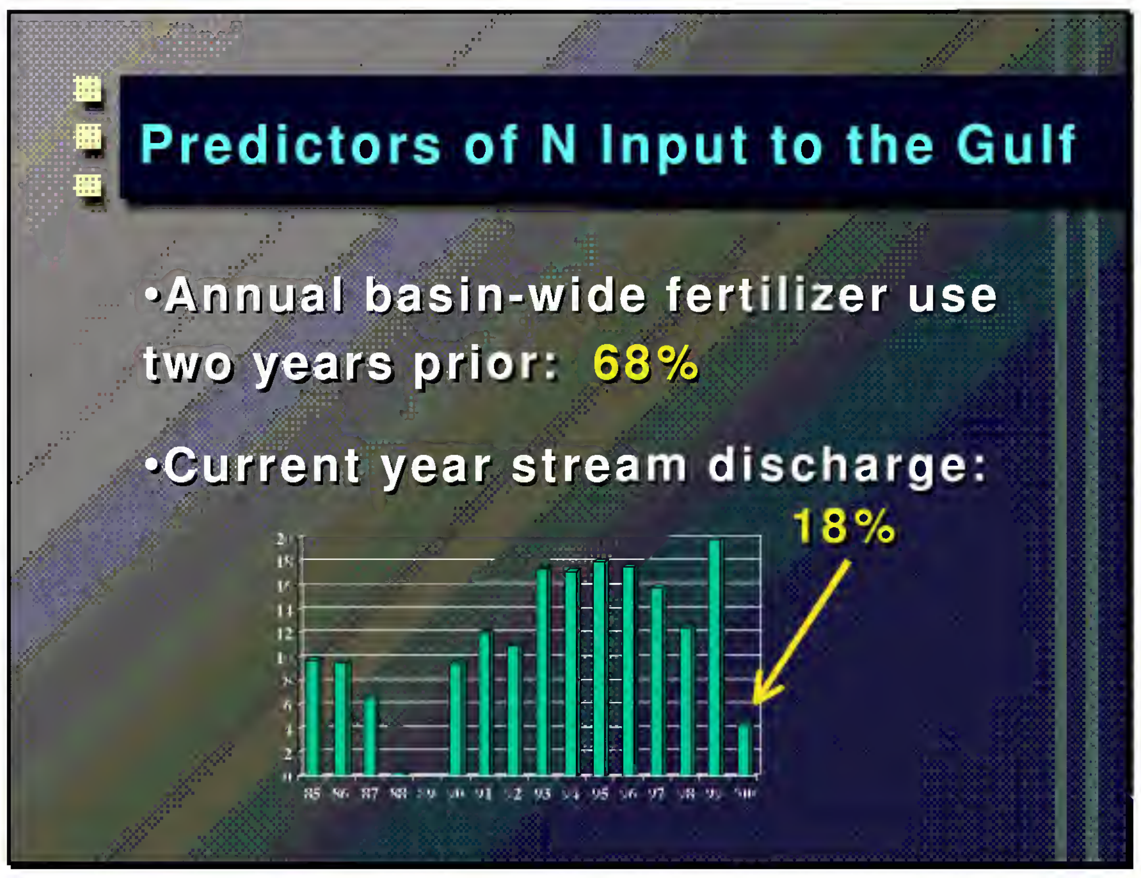

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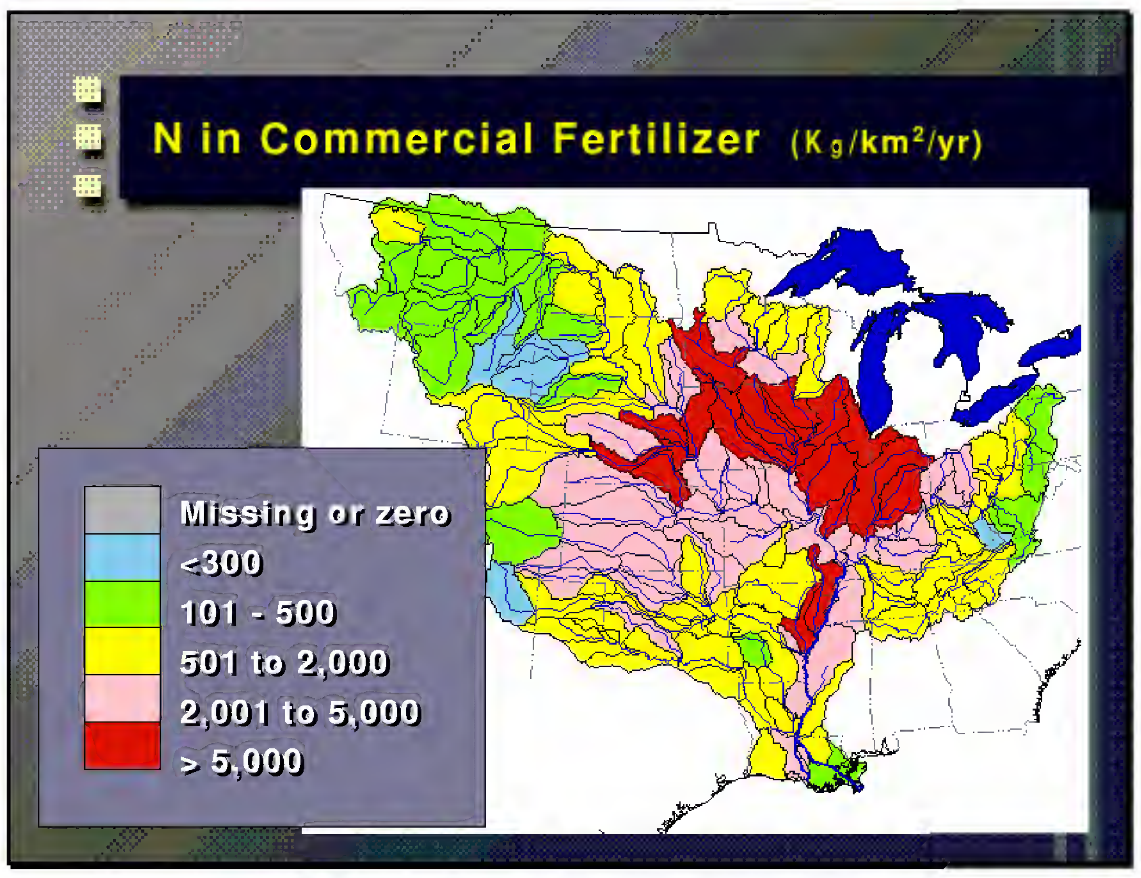

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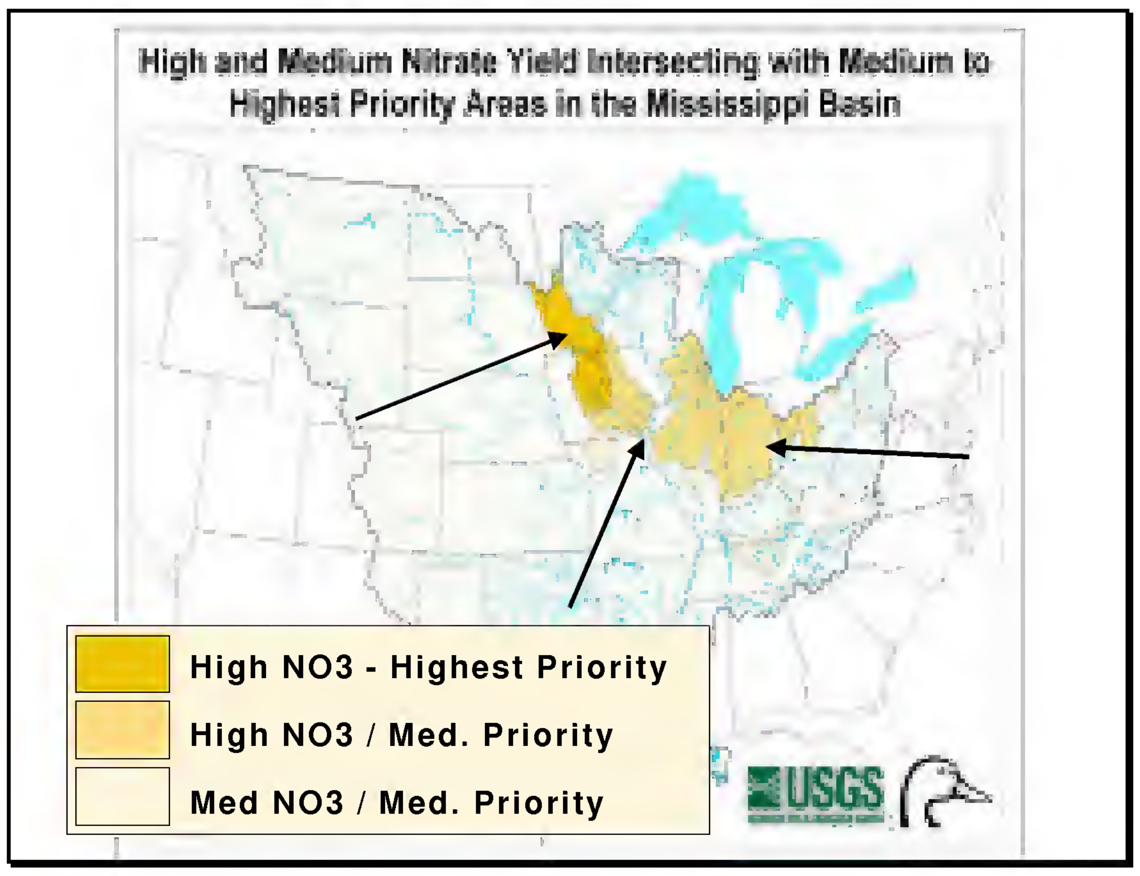

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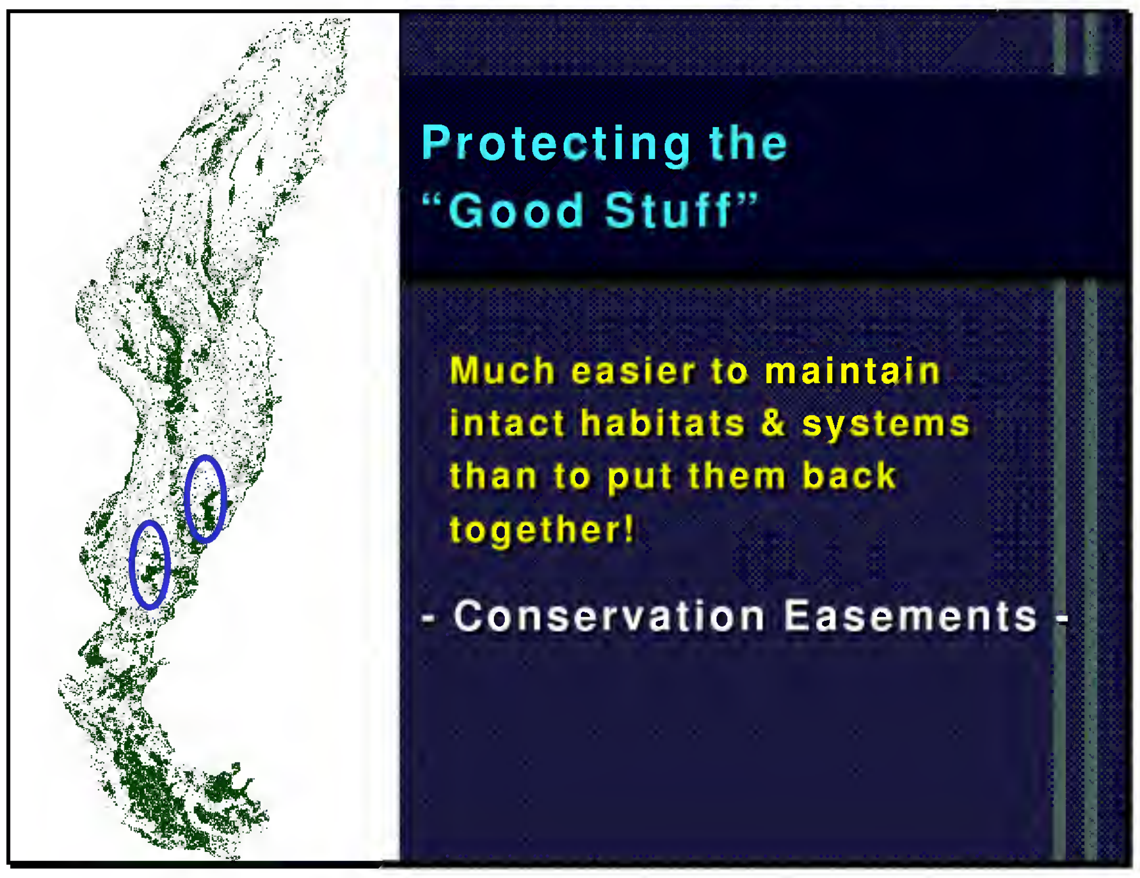

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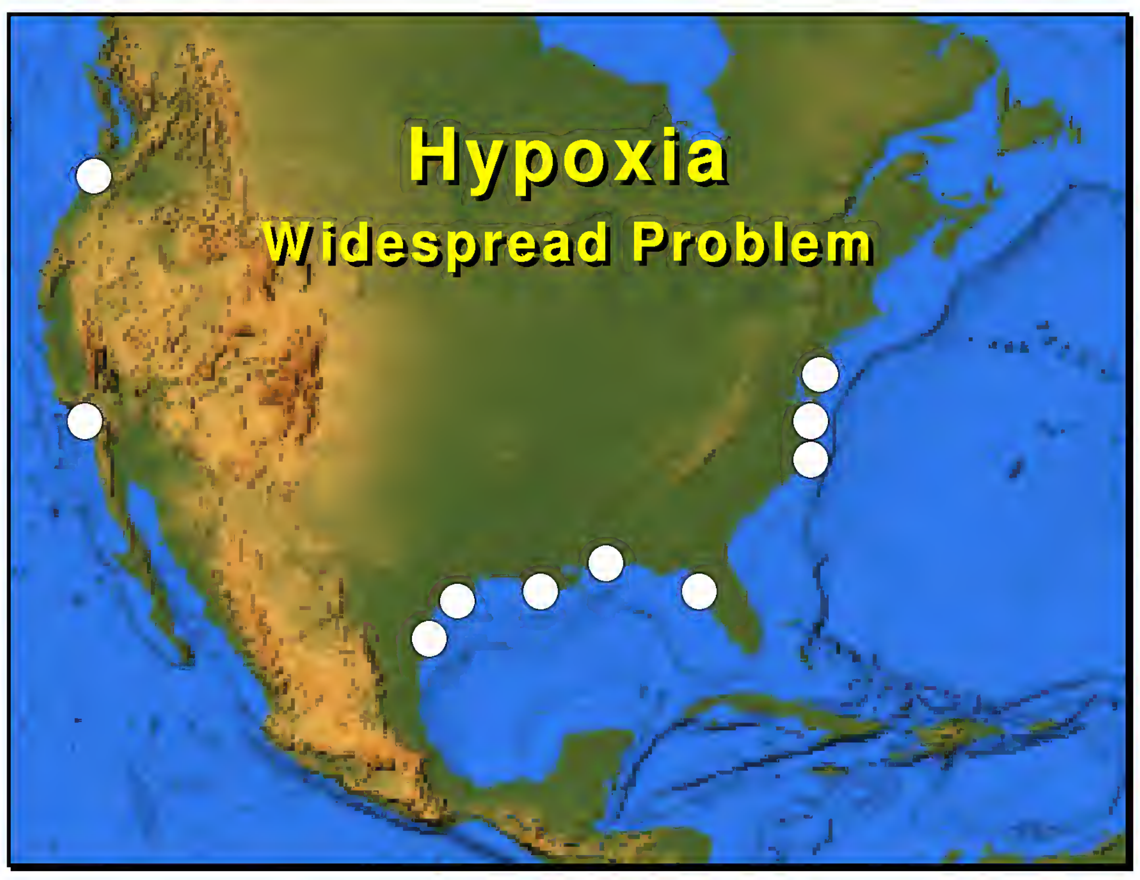

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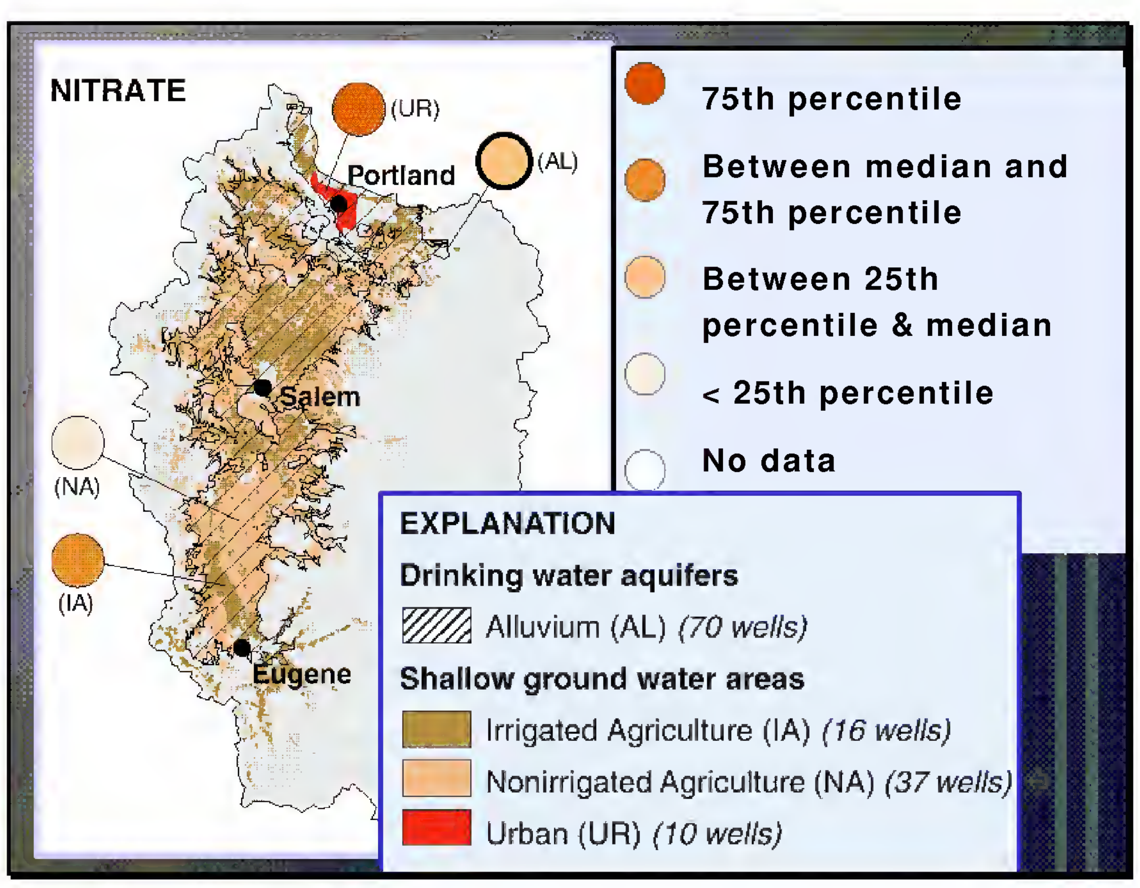

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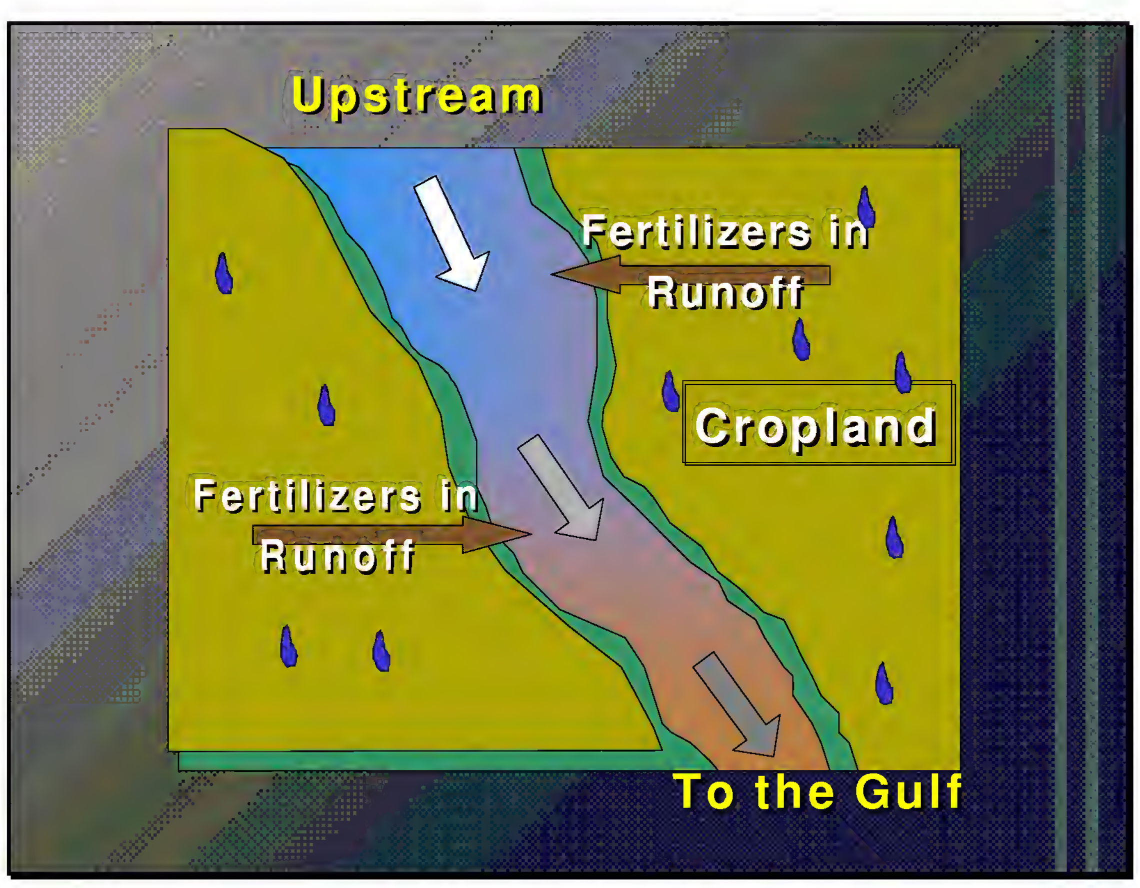

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